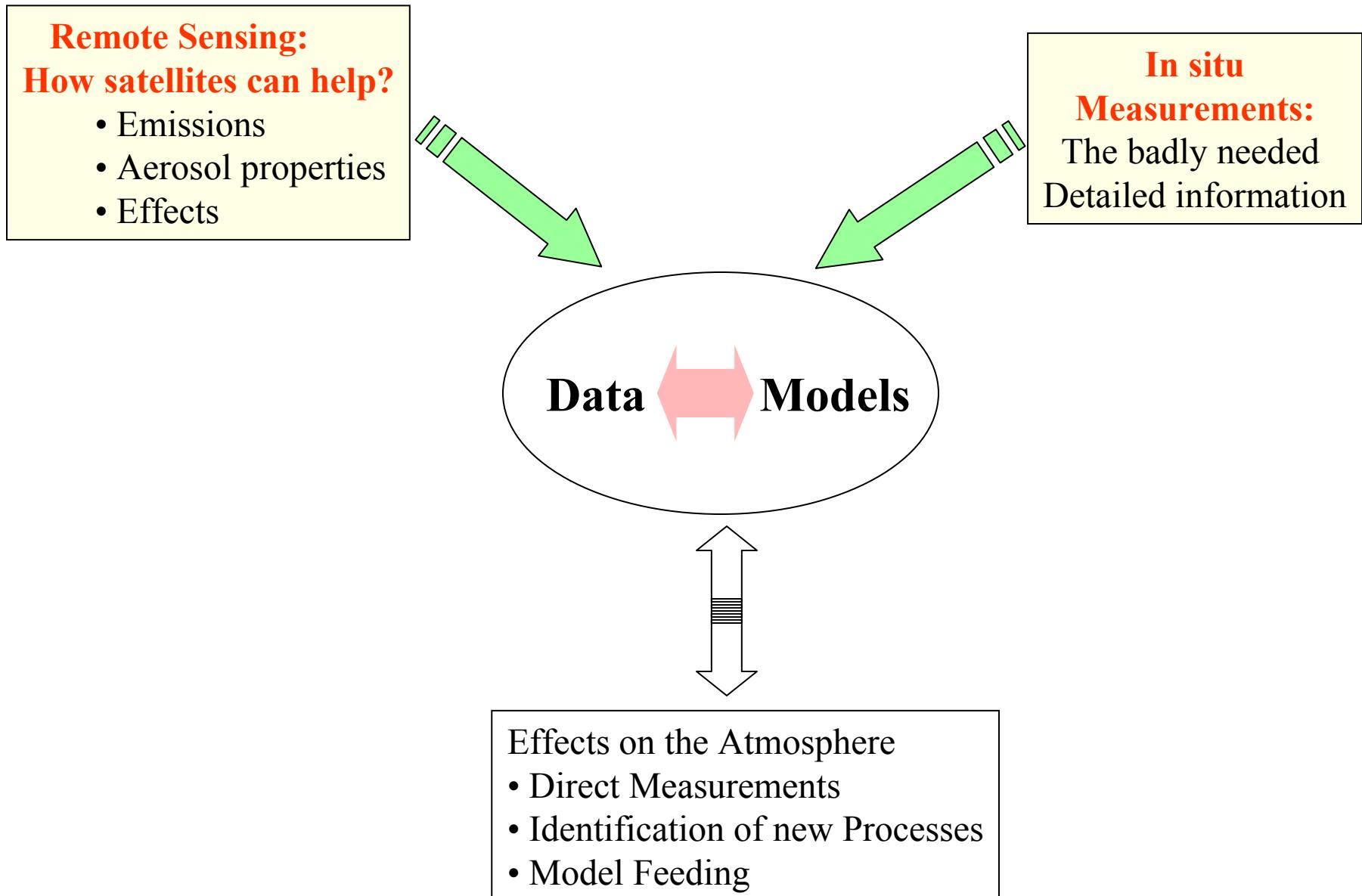


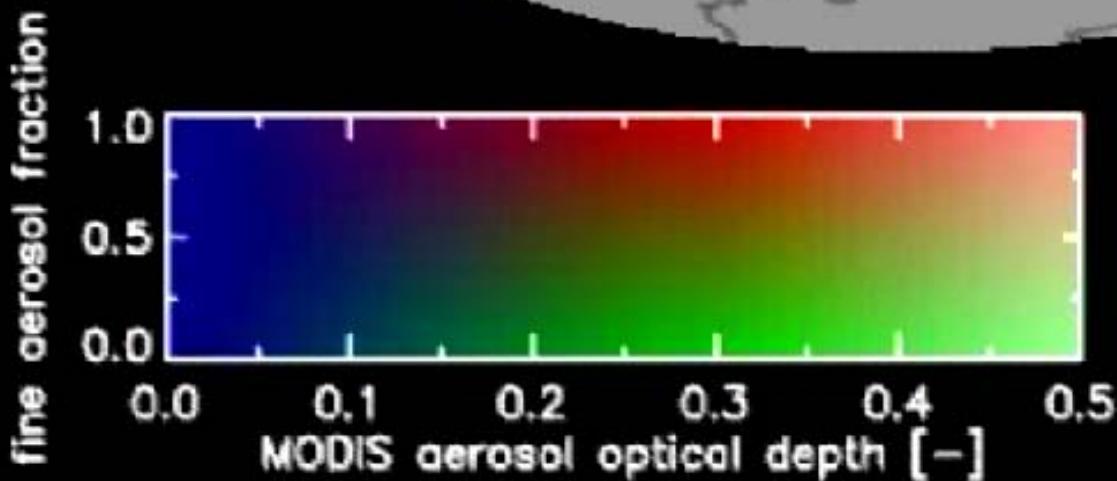
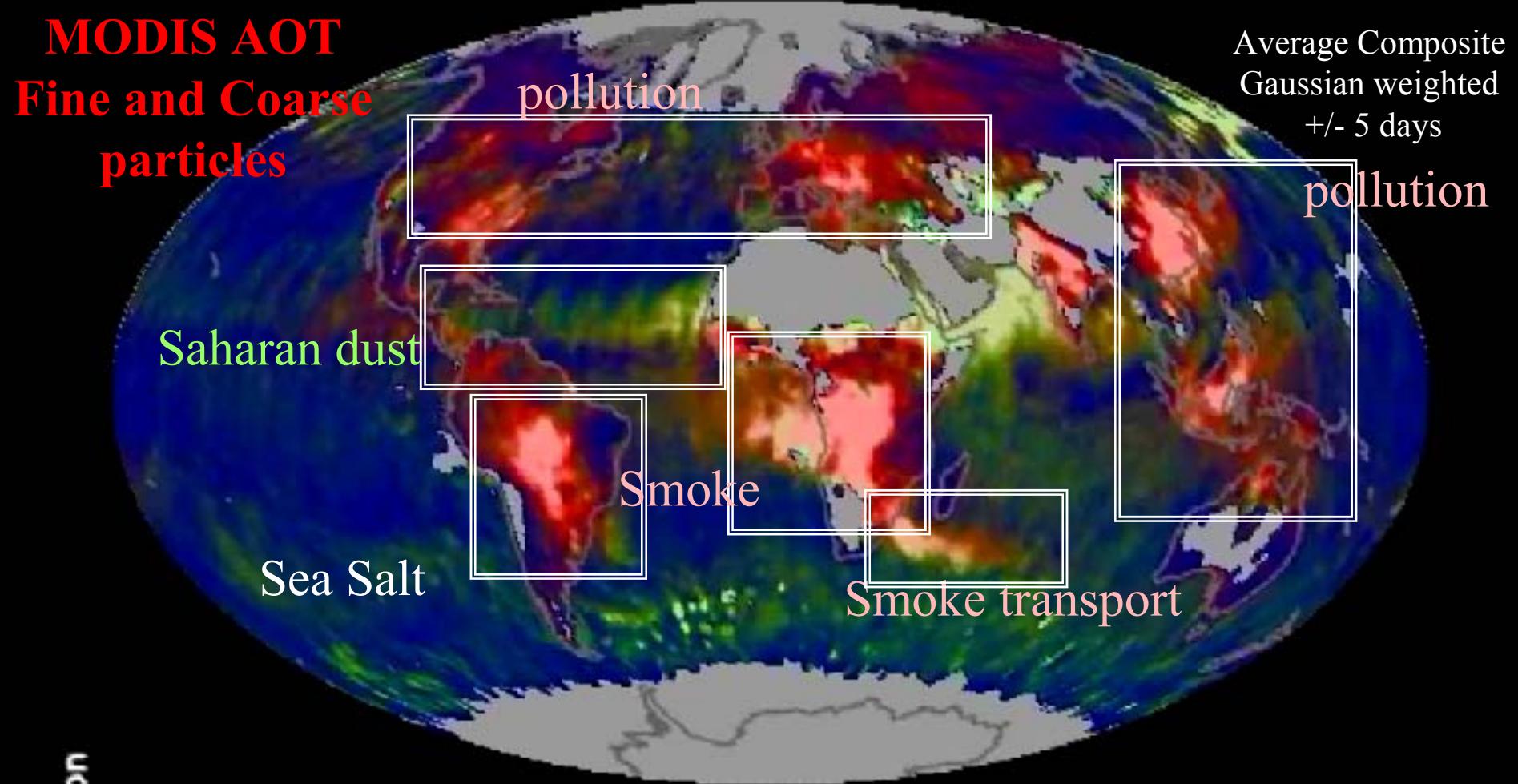
# Satellite and In Situ Measurements of Aerosol Emission, Burden and Microphysical Properties

**J. Vanderlei Martins** – JCET/Univ. Maryland, Balt.County, NASA GSFC, **Paulo Artaxo**  
– Univ. Sao Paulo, **Yoram Kaufman** – NASA GSFC

- **Remote Sensing**
  - How satellites can Help?
- **In Situ Measurements**
  - The Badly needed detailed microphysics
- **Effects**
  - Direct and Indirect Forcing

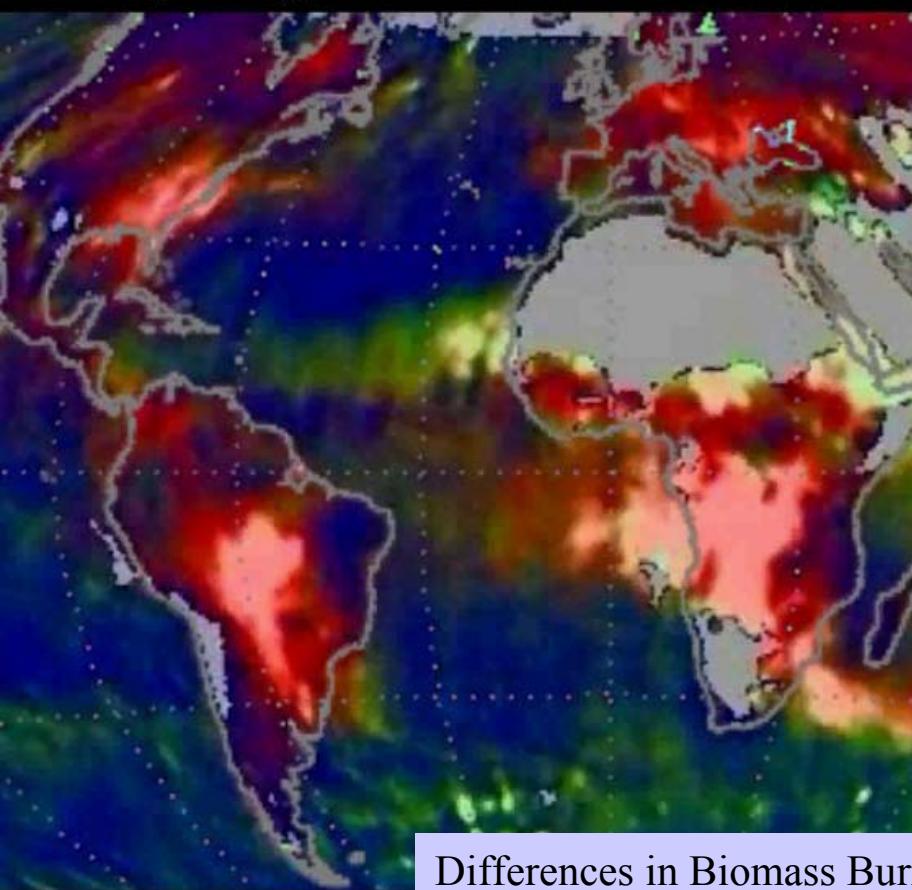
# Some missing links:



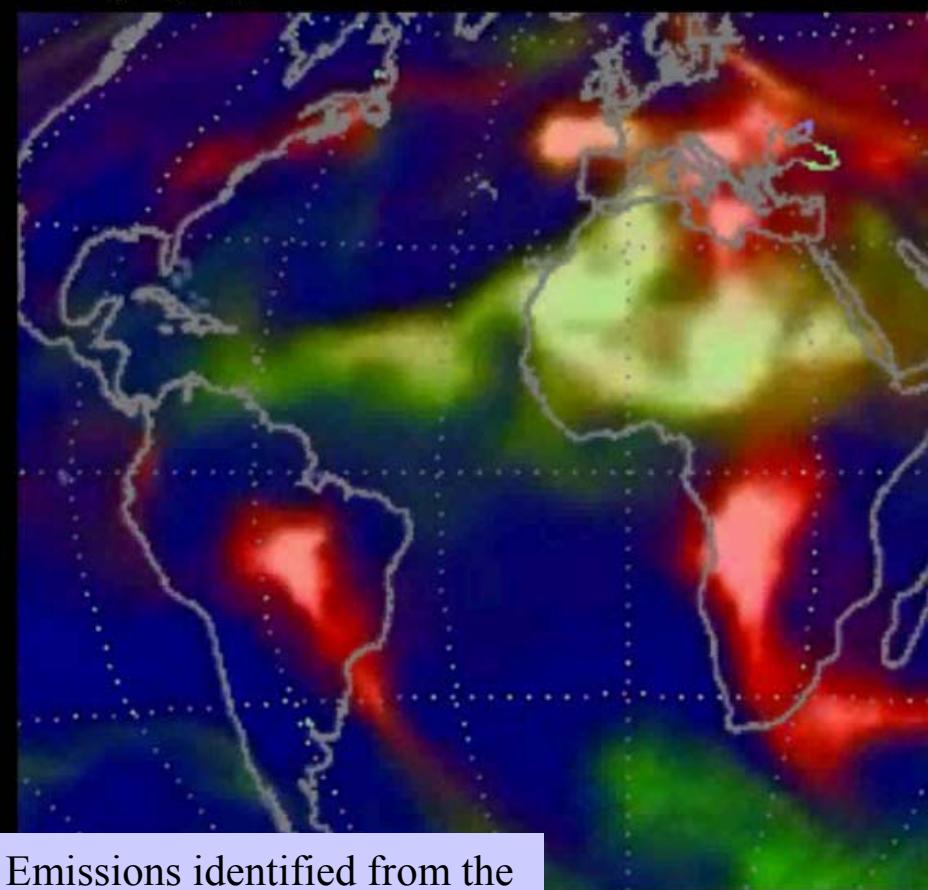


Red - pollution and smoke  
26 AUG 2001  
Green - dust and salt

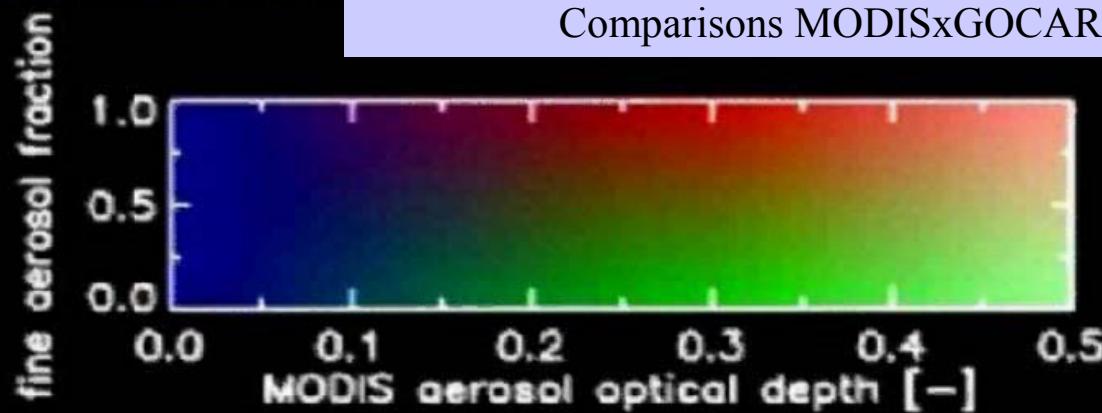
# MODIS



# GOCART



Differences in Biomass Burning Emissions identified from the  
Comparisons MODISxGOCART Model

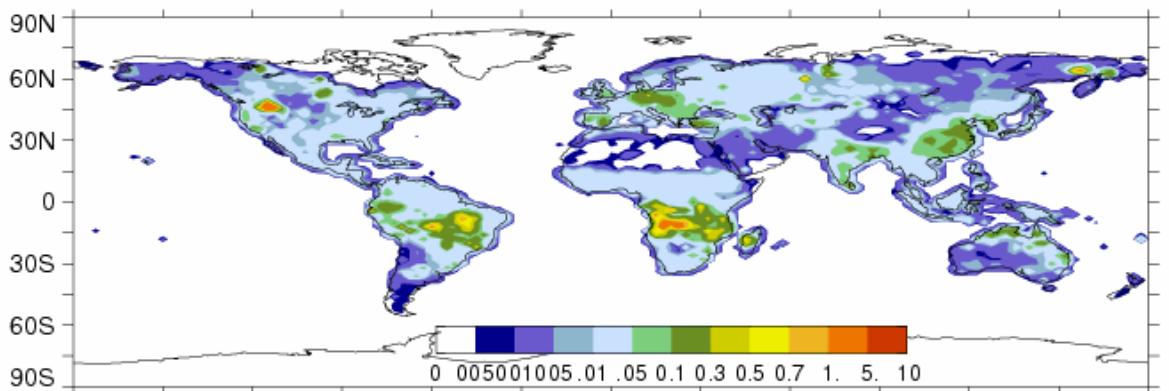


8/29/2001

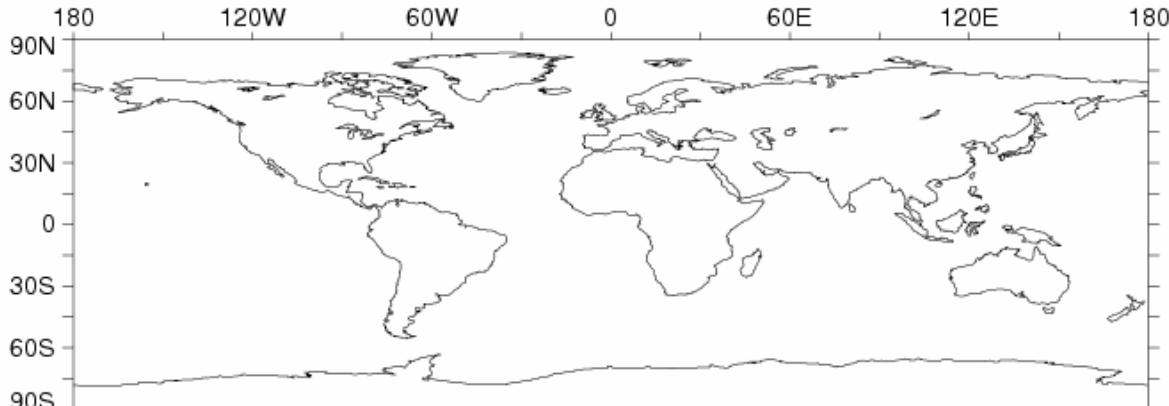
## Testing of inversion

GOCART  
sources

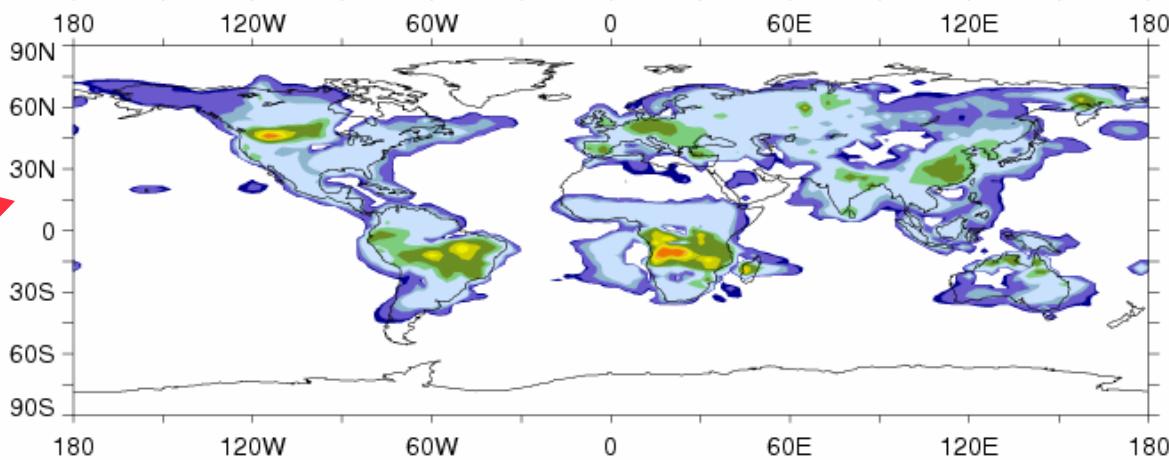
Emission Sources  
mass(mol)/1e+7 MODEL for August 28,2000



Initial guess  
For inversion

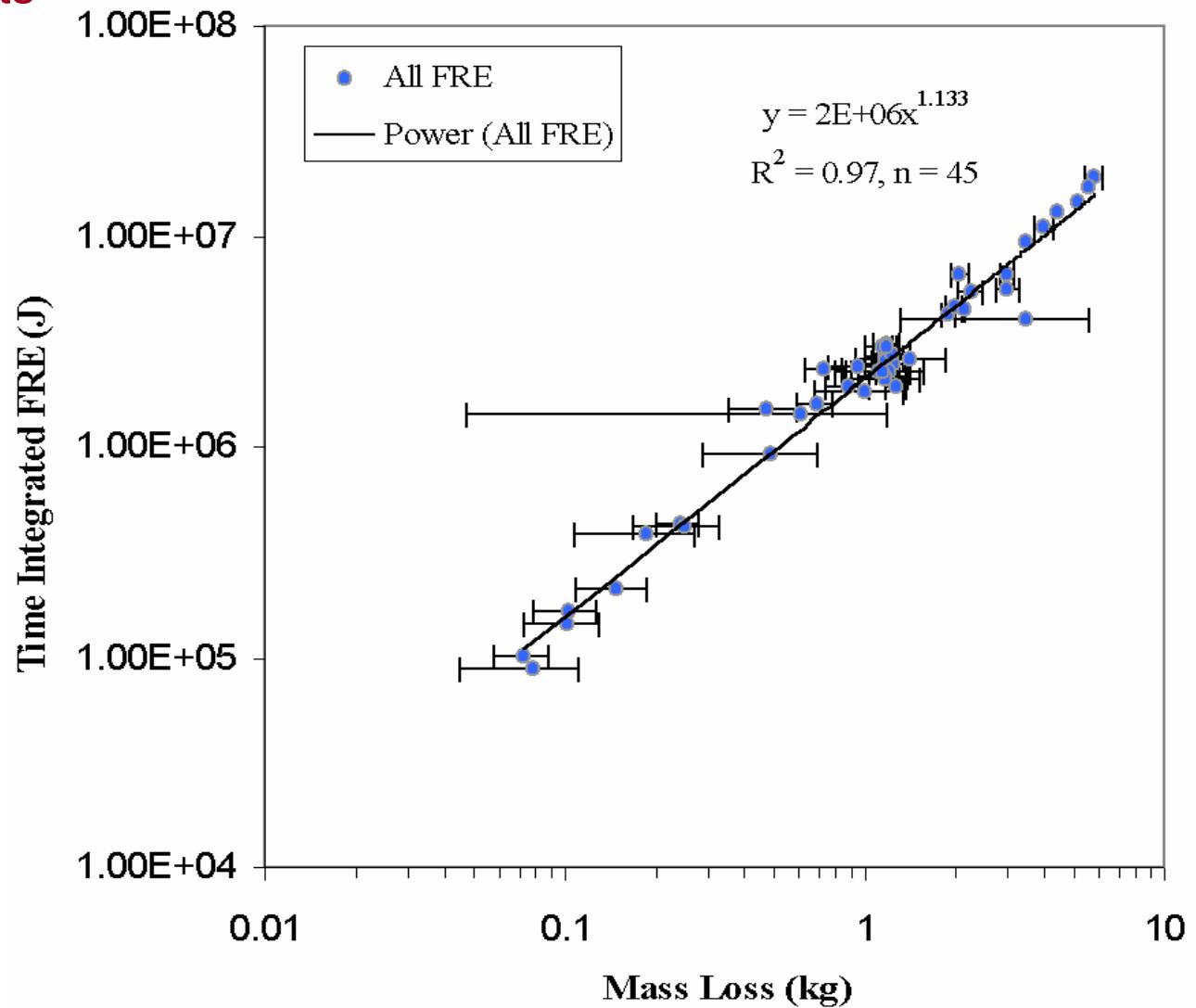


Retrieved  
Sources from  
GOCART simulation



# Correlation between Fire Radiative Energy (FRE) and Biomass Mass Loss

From field measurements  
(Martin Wooster,  
Univ. London, UK)



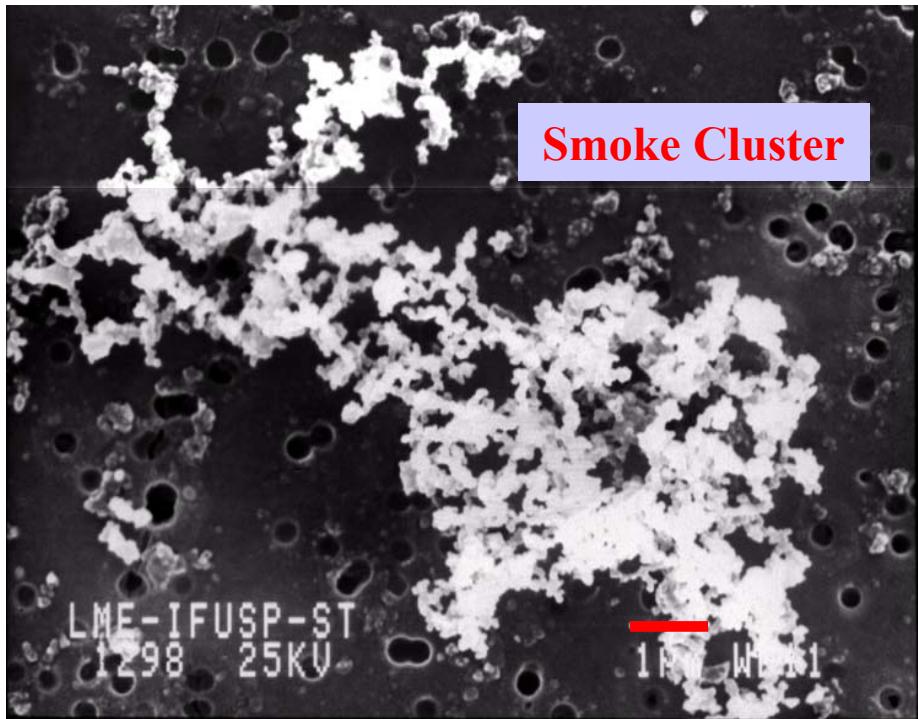
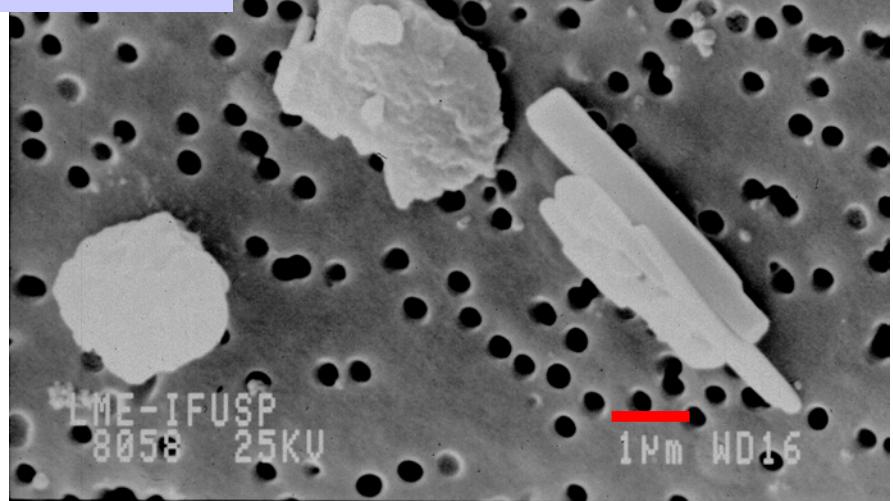
**Therefore the fire temperature or radiative energy is an indicator of the rate of biomass consumption and aerosol emission**

# Spectral Absorption Properties of Black Carbon and other Aerosols: Measurements and Effects.

**J. Vanderlei Martins** – JCET/Univ. Maryland, Balt.County, NASA GSFC, Paulo Artaxo  
– Univ. Sao Paulo, Yoram Kaufman – NASA GSFC

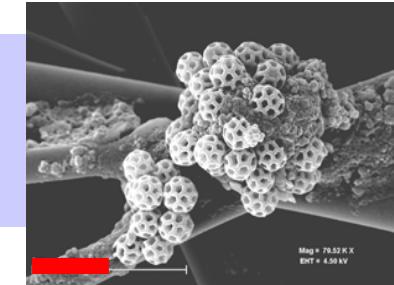
- **Common facts/myths about aerosol absorption:**
  - The main aerosol absorbers in the atmosphere are Dust and Black Carbon
  - Black carbon is only present in the fine mode
  - Dust absorption is flat from UV-NIR
  - Organic aerosols do not absorb light

## Saharan Dust in the US

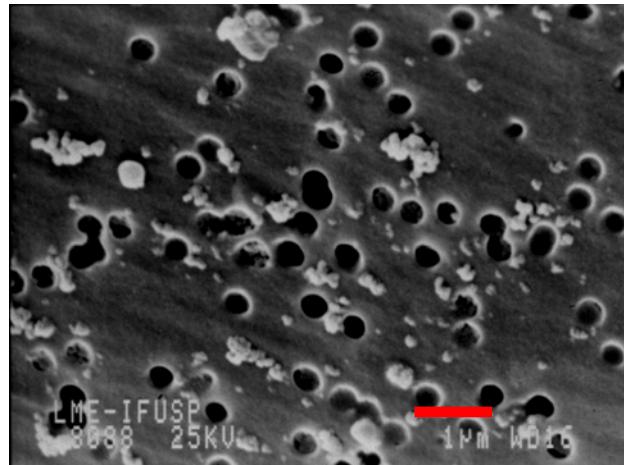
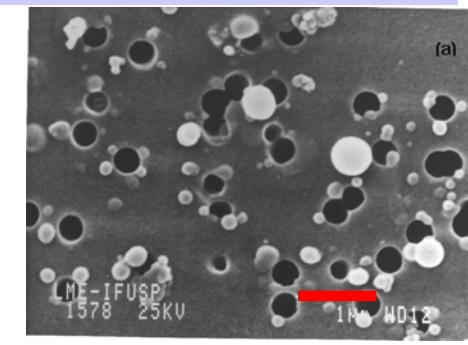
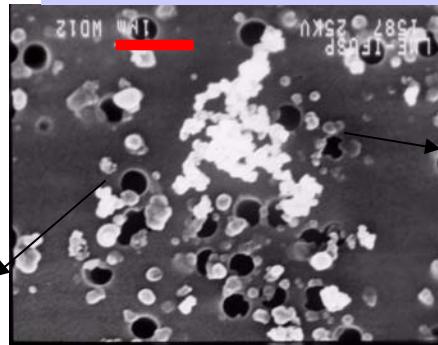


# Types of Particles

Amazon:  
Biogenic  
Cluster



Flaming      Smoke      Smoldering



US  
Urban  
Pollution

# My Favorite Unit to Report Absorption: $\text{m}^2/\text{g}$ :

- Relates aerosol mass and optical properties connecting measurements and models.
- **Aerosol Absorption Efficiency**
  - Absorption Cross Section per unit of aerosol mass
- **Black Carbon Absorption Efficiency**
  - Absorption Cross Section per unit of BC mass
  - BC mass 5-15 % of Aerosol mass

**BC absorption Efficiency**  
~ 10X Aerosol Abs. Eff.

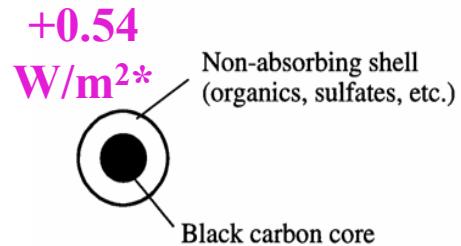
# My Favorite Unit to Report Absorption: $\text{m}^2/\text{g}$ :

- **Aerosol Absorption Efficiency:**  $\alpha_A$  ( $\text{m}^2/\text{g}$ )
  - Absorption Coef. ( $\text{m}^{-1}$ )/Mass concentration ( $\text{g}/\text{m}^3$ )
  - BCratio = Mass BC/Total Mass
- **Black Carbon Absorption Efficiency:**  $\alpha_{BCA}$  ( $\text{m}^2/\text{g}$ )
  - Absorption Coef. ( $\text{m}^{-1}$ )/BC Mass concentration ( $\text{g}/\text{m}^3$ )
  - BC ratio Biomass Burning 5-15 % of Aerosol mass
  - $\alpha_{BCA} = \alpha_A \cdot \text{Bcratio}$
- **Relates Mass with Radiative Properties**
  - Satellite measures AOT
  - $\text{AOT} = (\text{g}/\text{m}^2)_{\text{total column}} \cdot \alpha_A$

## Microphysical Properties of Aerosol Particles

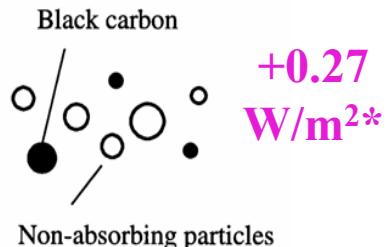
e.g.: Light Absorption Efficiencies and BC contents

Internal mixing with layered structure:



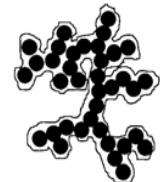
$$\alpha_{abs} = 1 - 25 \text{ m}^2/\text{g}$$

External mixing:

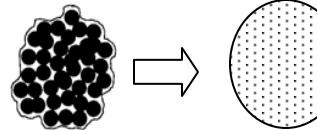


$$\alpha_{abs} = 1 - 10 \text{ m}^2/\text{g}$$

Internal mixing in soot aggregates



Closed soot cluster



$$\alpha_{abs} = 2 - 30 \text{ m}^2/\text{g}$$

**+0.78**  
**W/m<sup>2</sup>\***

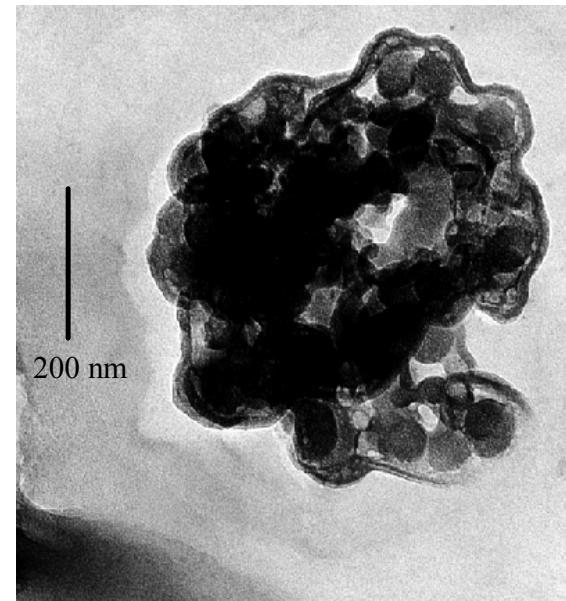
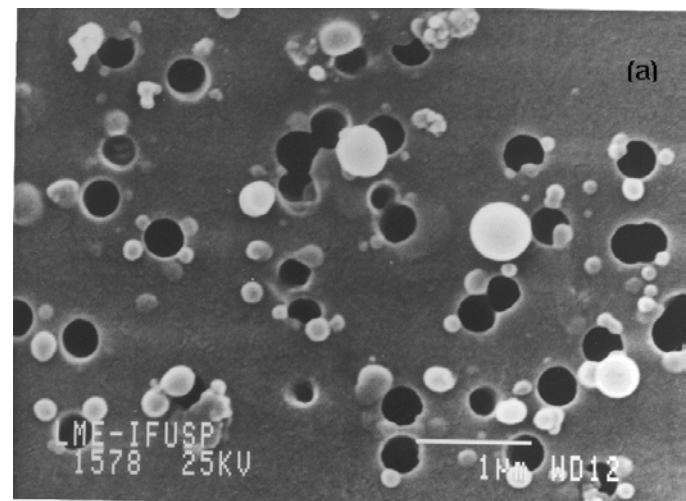
Homogeneous internal mixture

$\alpha_{aBC}$  measurements 5 - 22 m<sup>2</sup>/g

\* Global DRF by Jacobson, 2000.

Martins et al., 1998

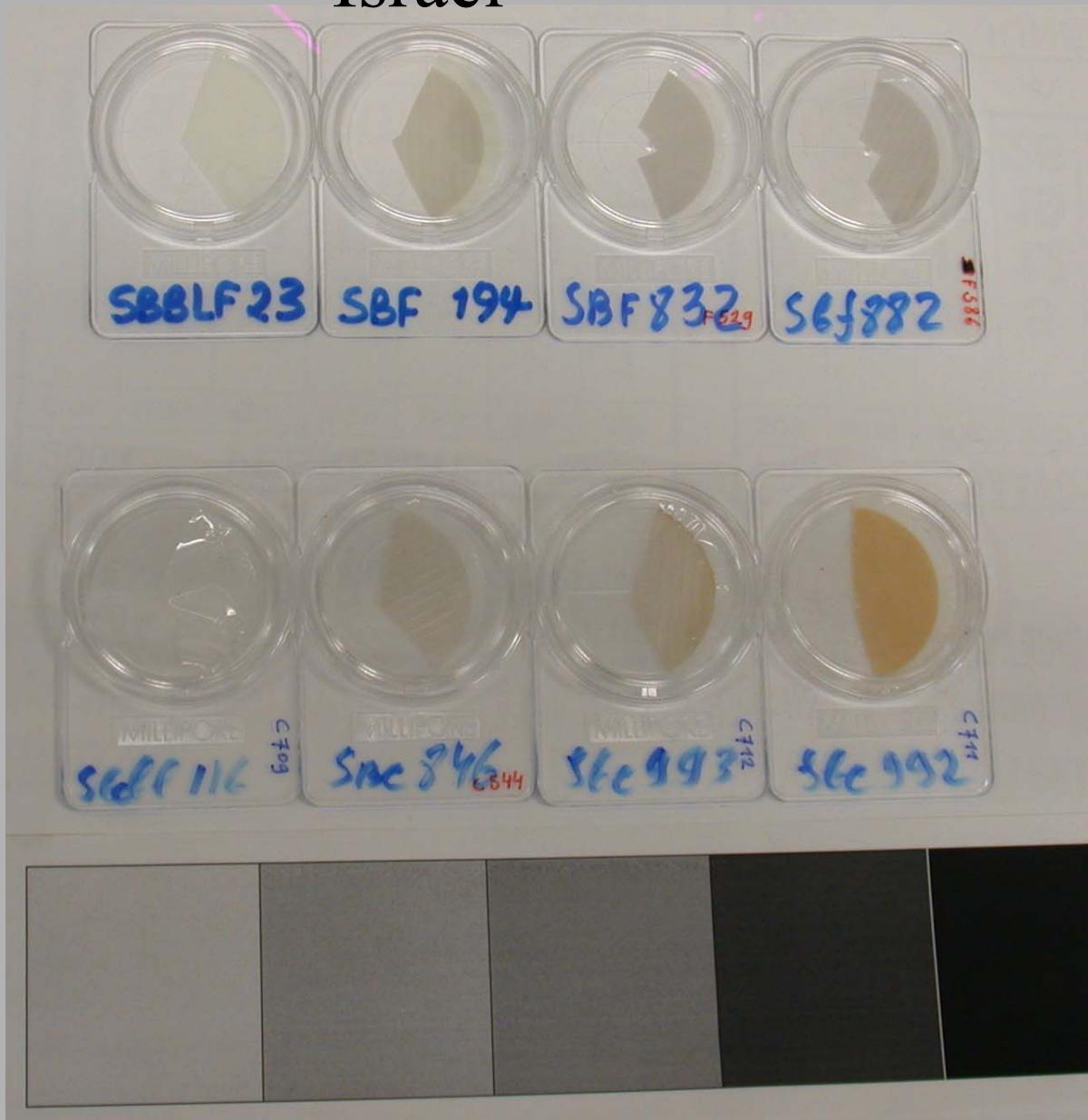
# Large Variability in BC Absorption Properties!!!



# Dust + Pollution Samples from Sahara collected in Israel

Particles  
 $< 2.5\mu\text{m}$

$2.5 - 10\mu\text{m}$

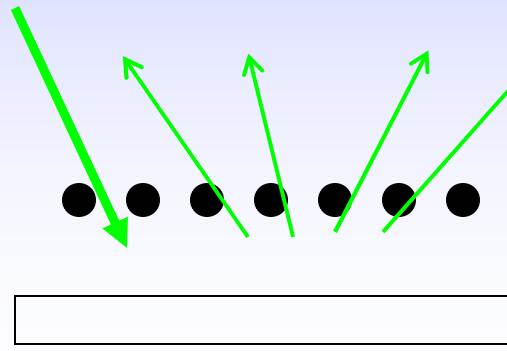


# Remote sensing of filter Samples

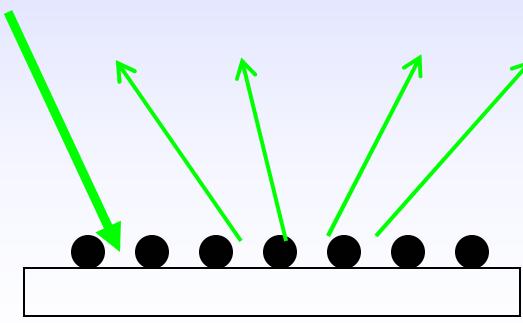
Simple strategy for Remote Sensing and in Situ:

Particles Reflectance over bright surfaces

Particles in suspension in  
the atmosphere



Particles collected on  
filter's surface

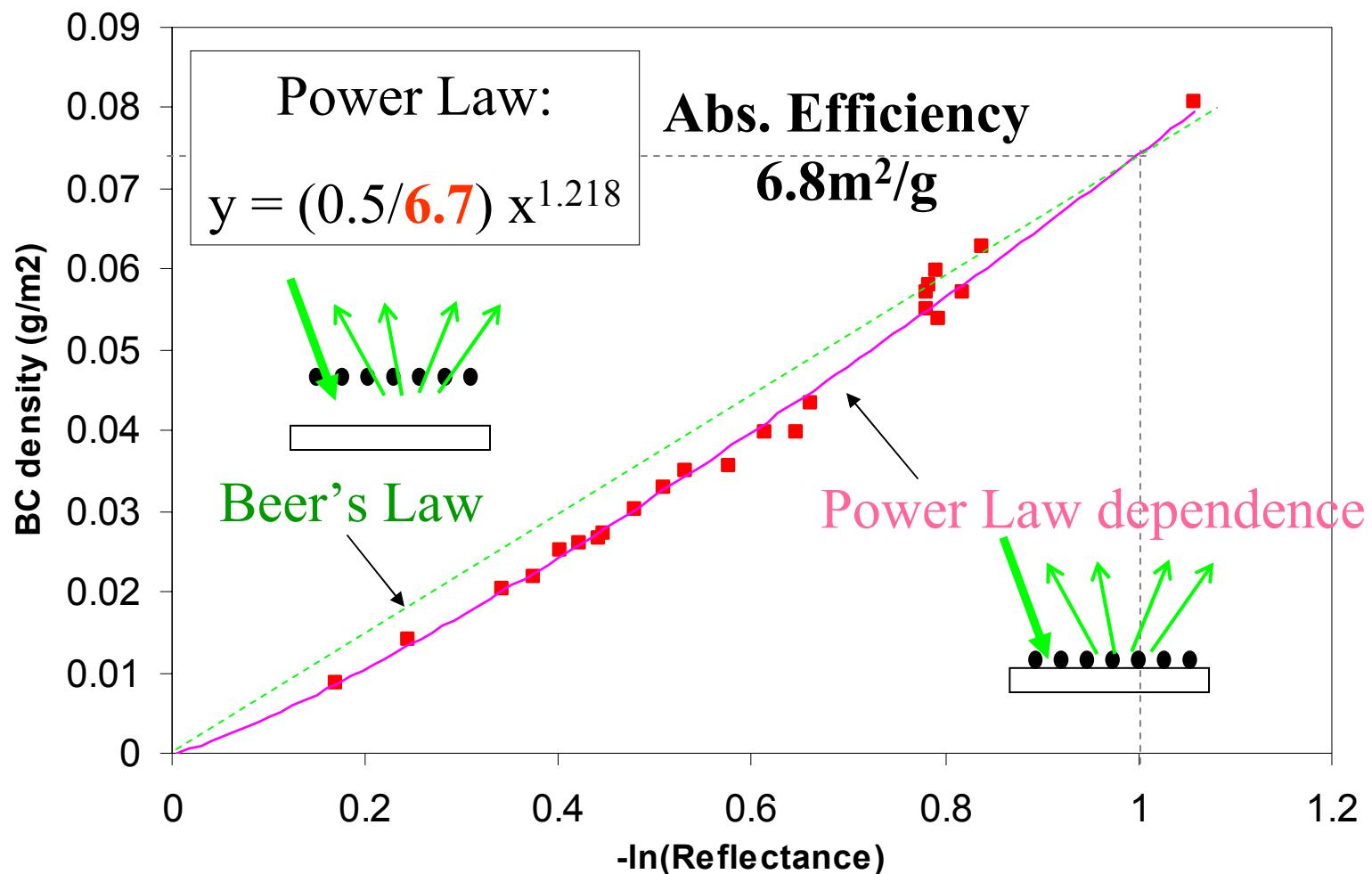


Has already been used for a long time...

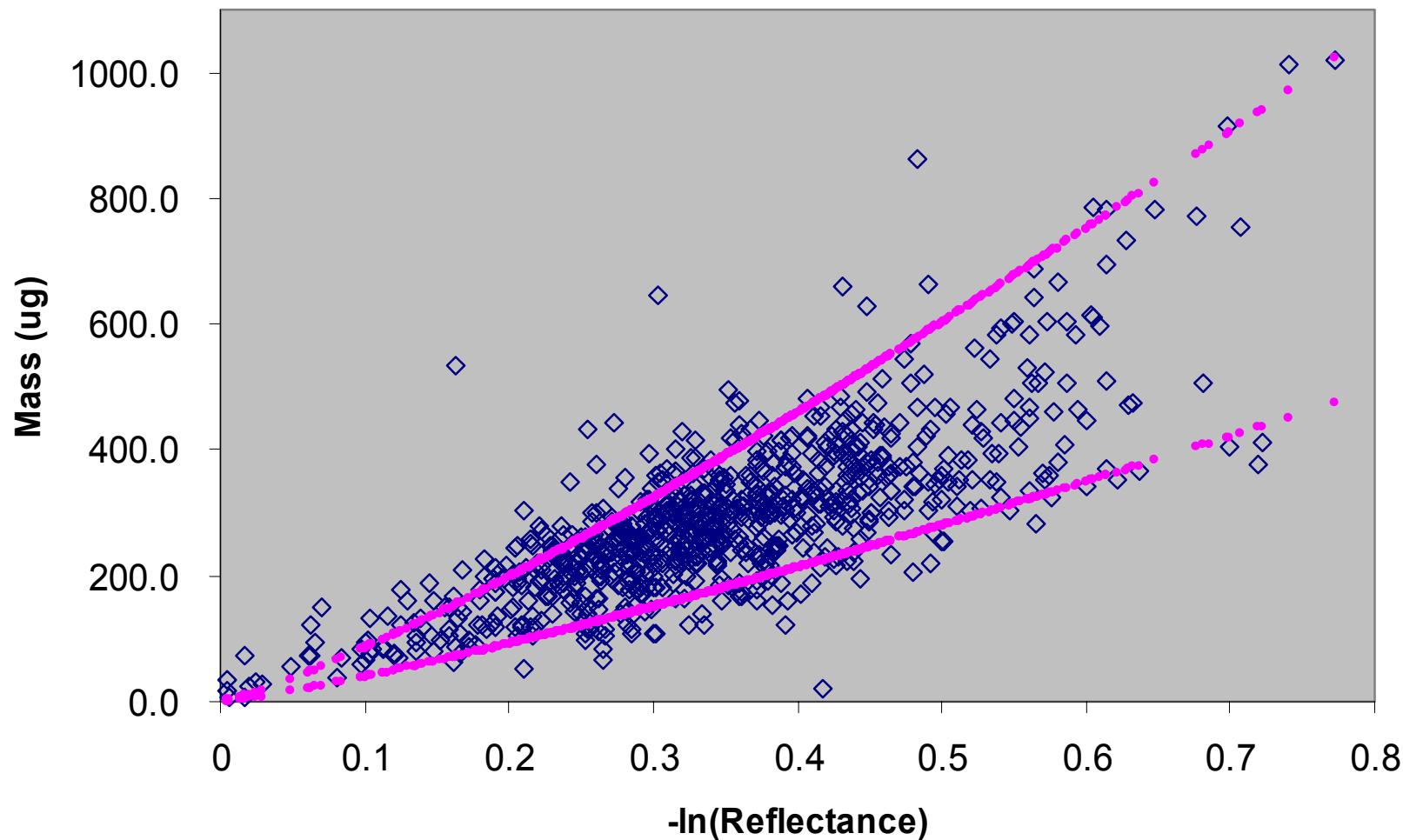
Needs good calibration and Interpretation of the results.

# Semi-Empirical Calibration:

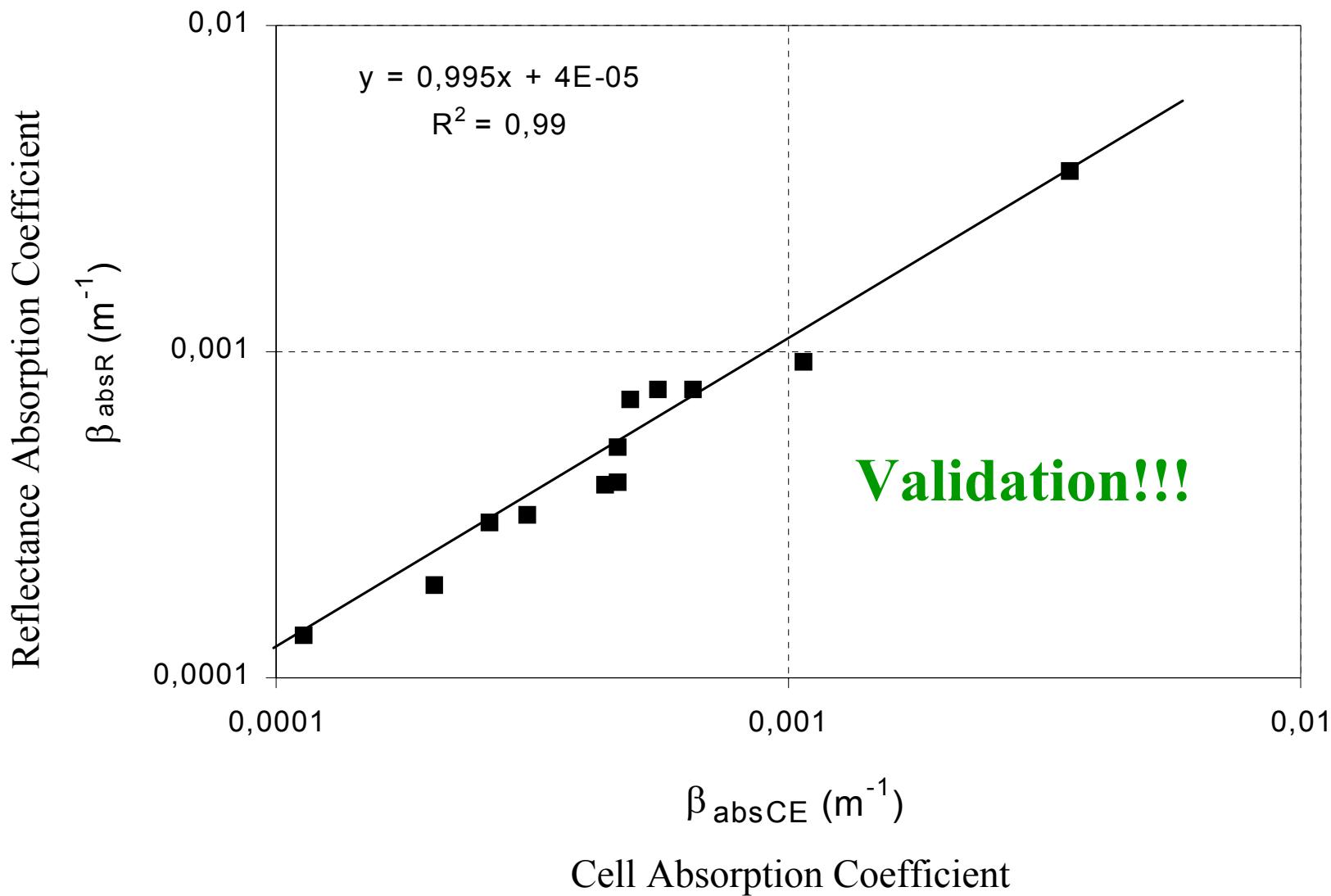
Aerosol Reflectance versus Mass Density for BC Standard Particles



## Absorption Efficiency - Alta Floresta Aerosols Power Law Model



# Reflectance Technique versus the University of Washington Extinction Cell for biomass burning particles in Brazil



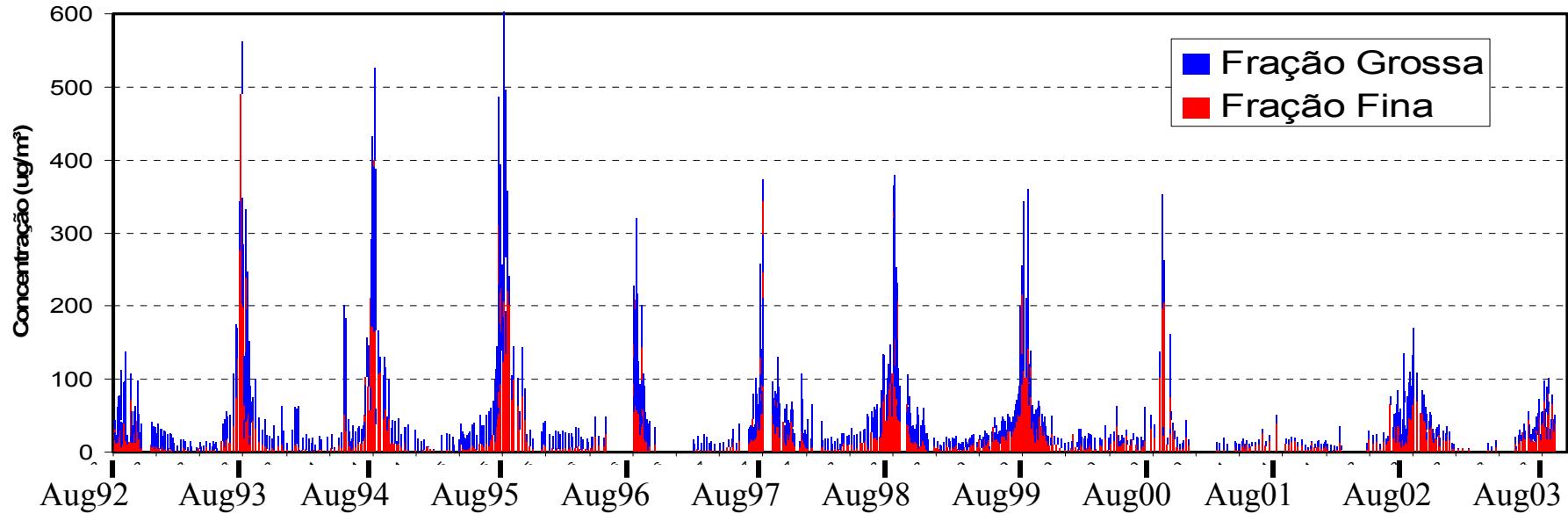


*Clear day*  
Visibility ~ ??? km  
 $N_{CN} \sim 500 \text{ cm}^{-3}$   
 $BC \sim 0.2 \mu\text{g m}^{-3}$

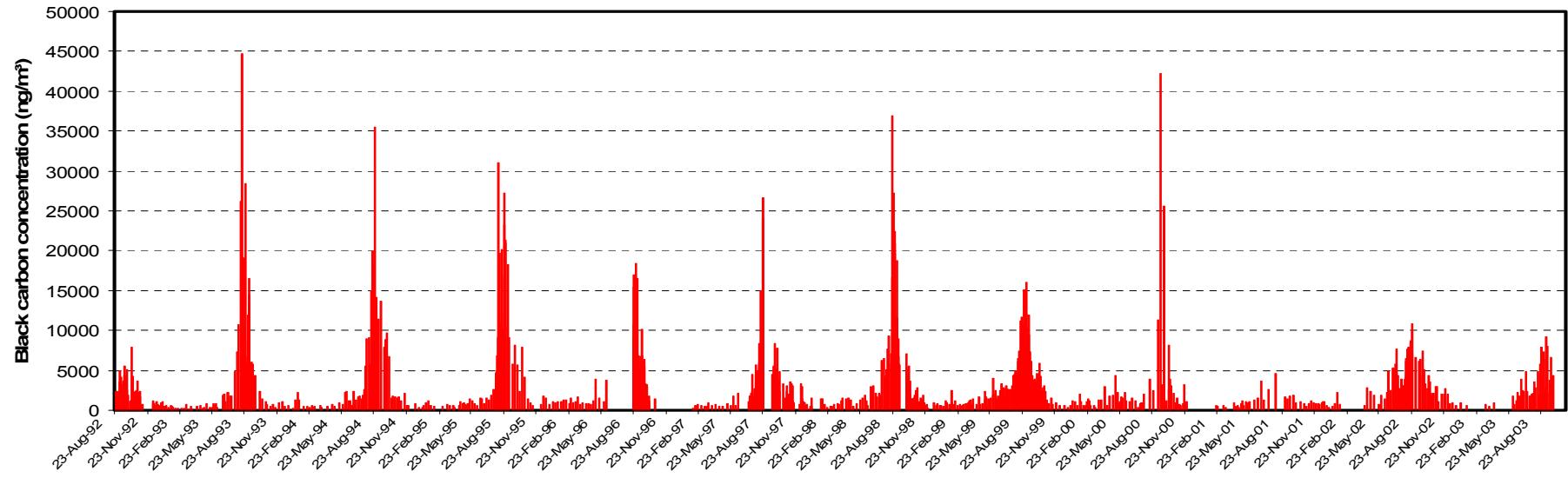


*Smoke haze*  
Visibility ~ 800 m  
 $N_{CN} \sim 10000 \text{ cm}^{-3}$   
 $BC \sim 7 \mu\text{g m}^{-3}$

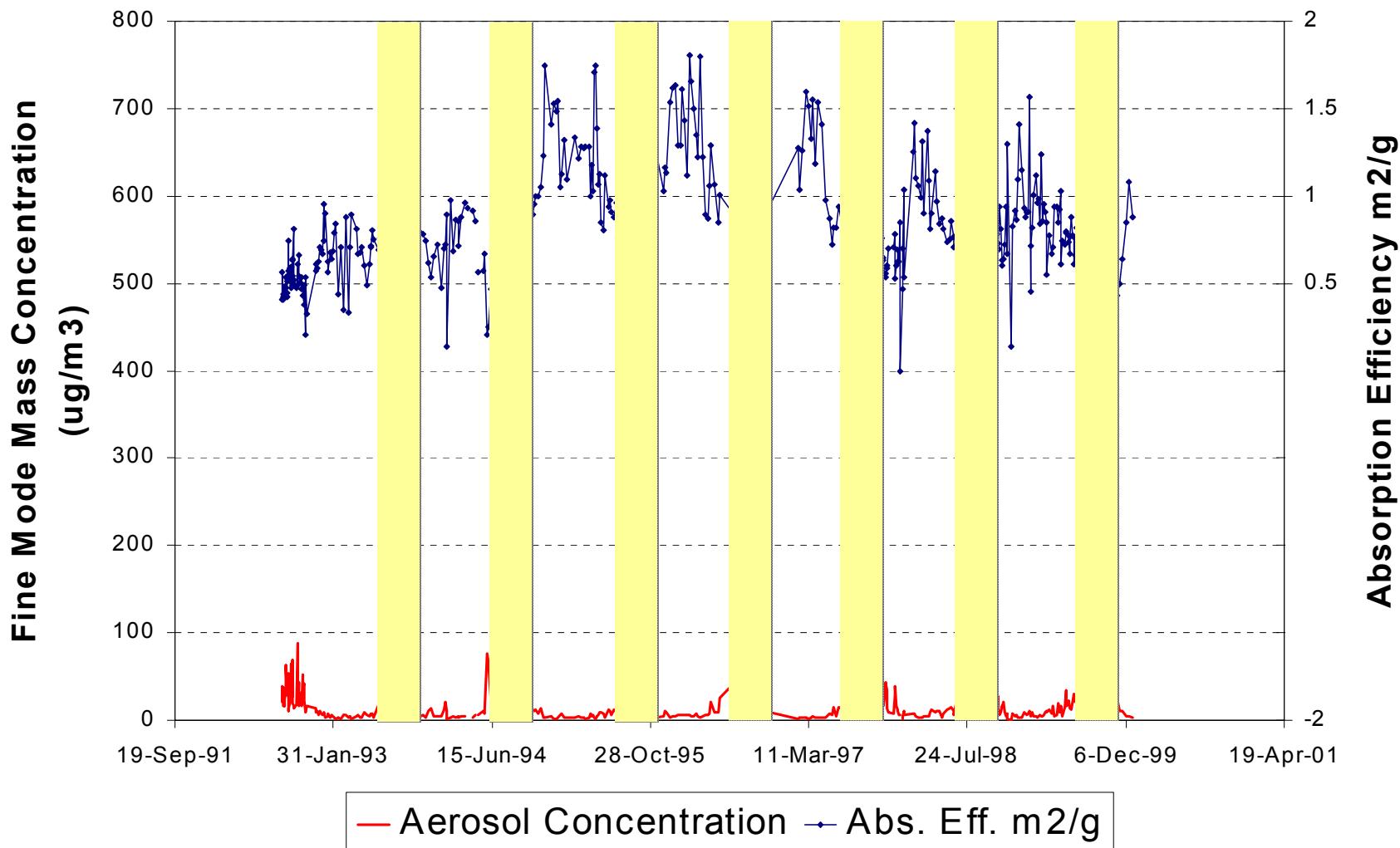
## Concentração de aerossóis em Alta Floresta Aug 1992 - Feb 2004



## Alta Floresta Black carbon fine mode aerosol 1992-2004

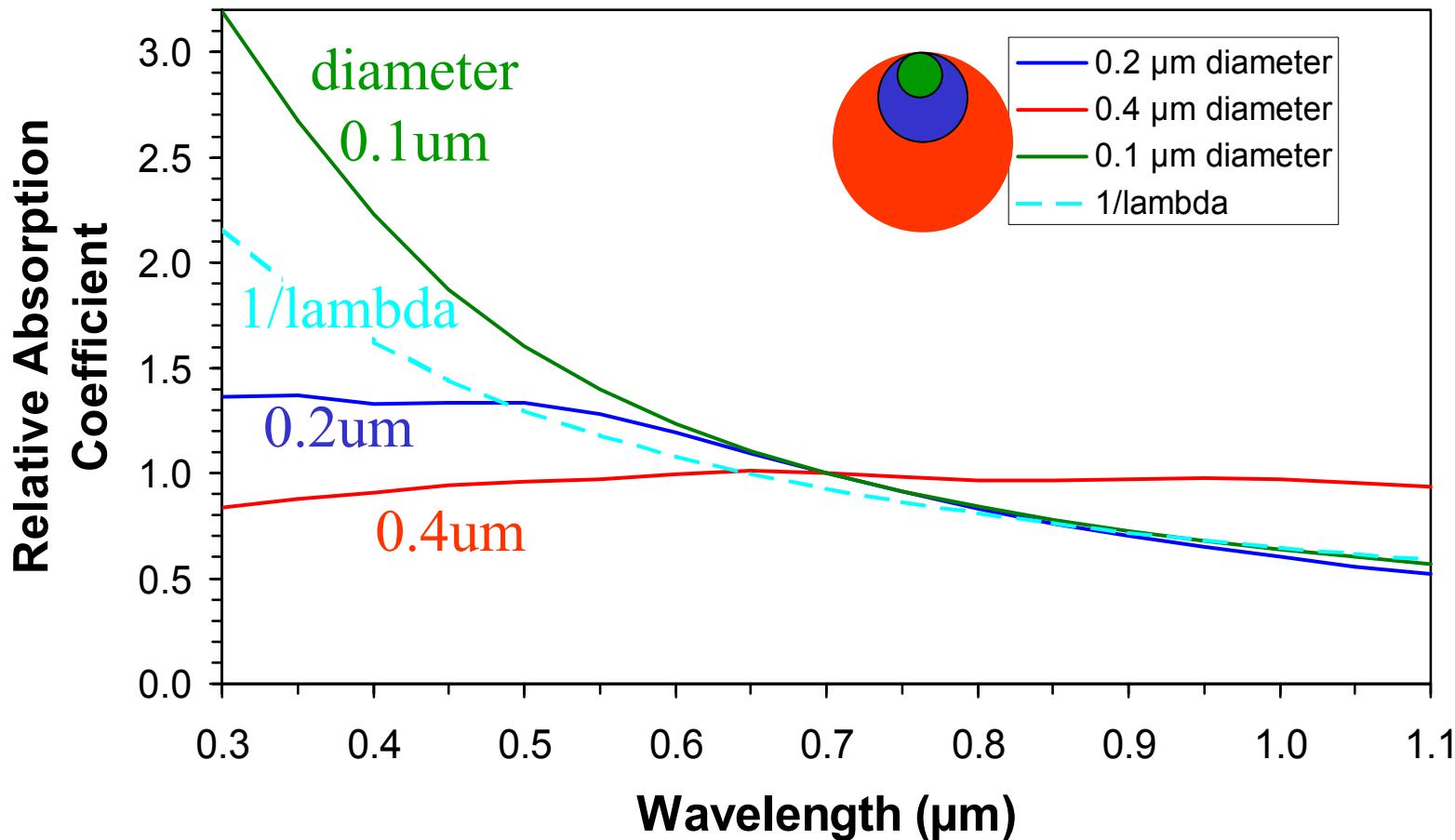


# But Not Only Smoke and Dust Absorbs Light...



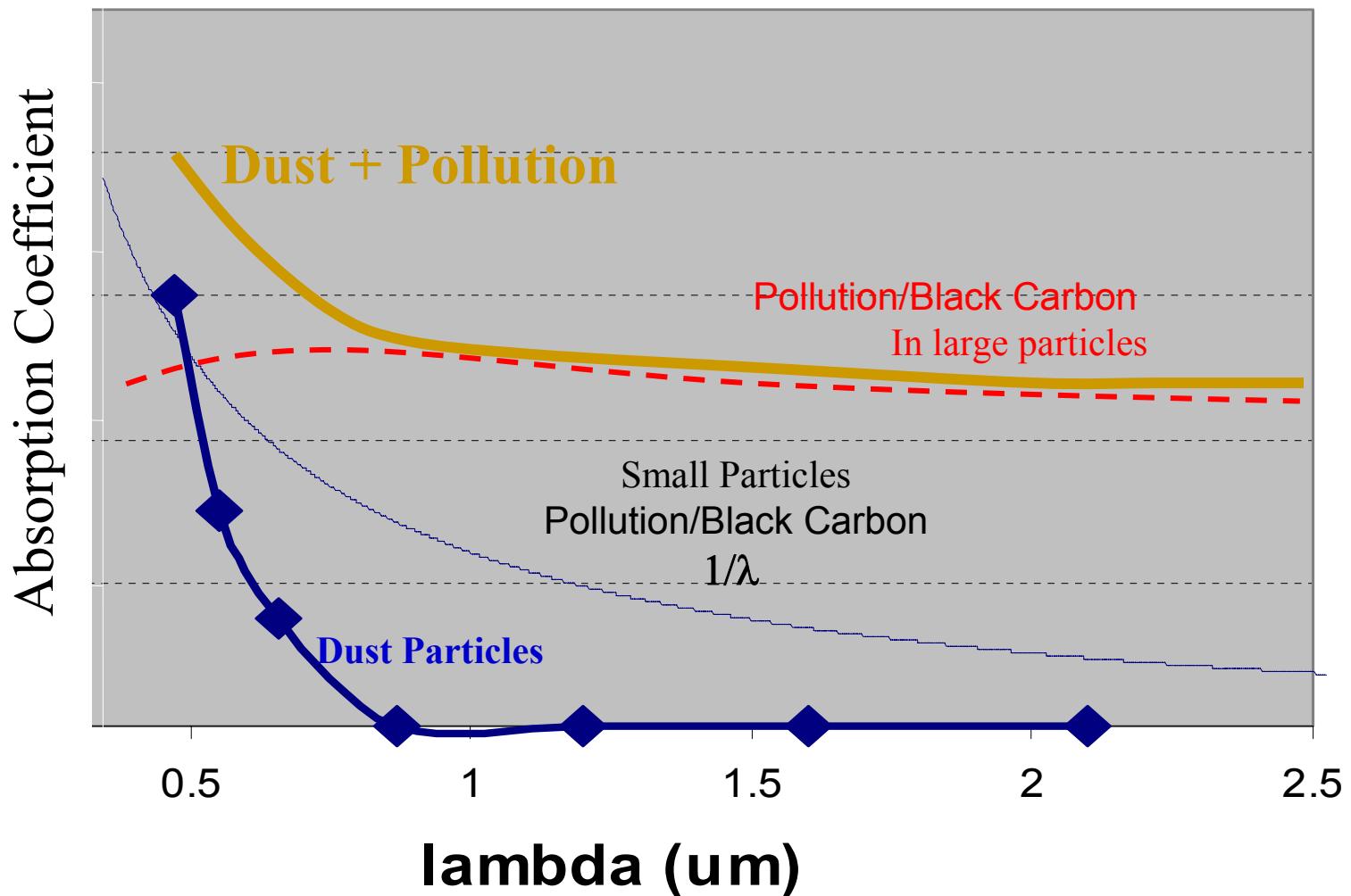
# Effect of Particle Size and Refractive Indices on Aerosol Absorption

**Mie Black Carbon Abs. Coefficient (Hobbs, 1993)**  
with constant refractive index of  $m=2.0-0.64i$



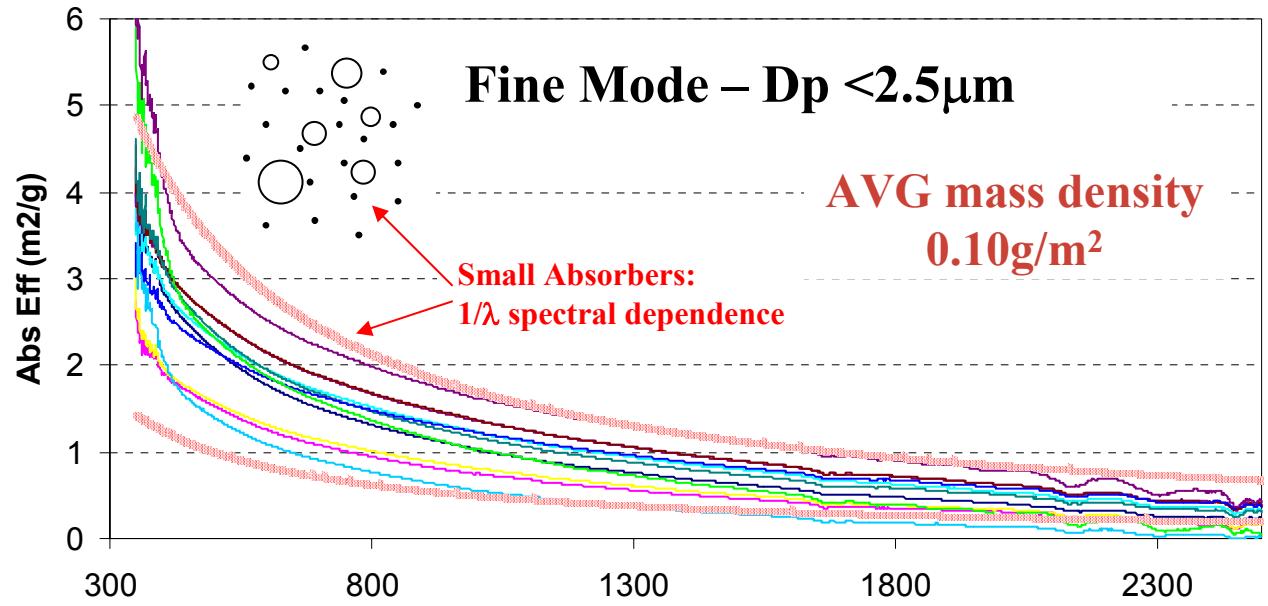
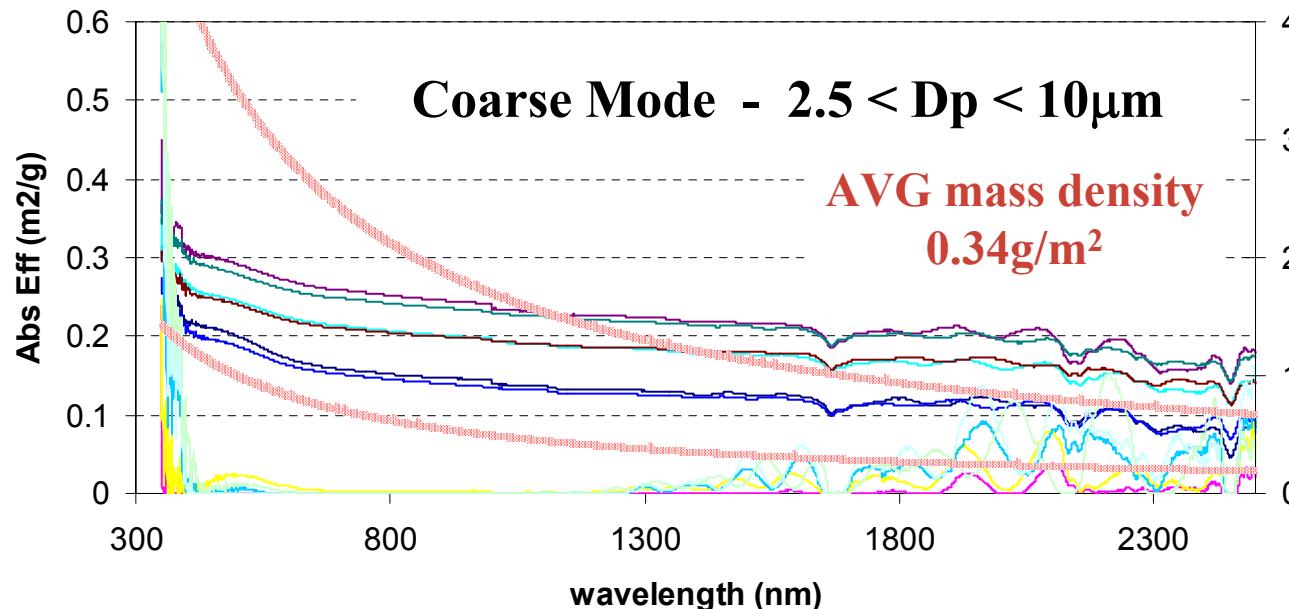
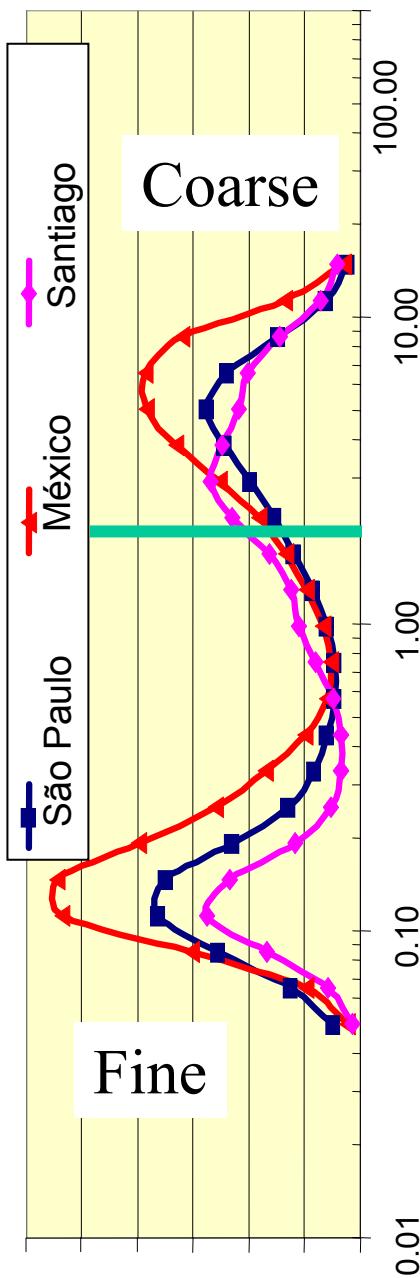
Courtesy of D. Savoie

# Expected Aerosol Spectral Absorption

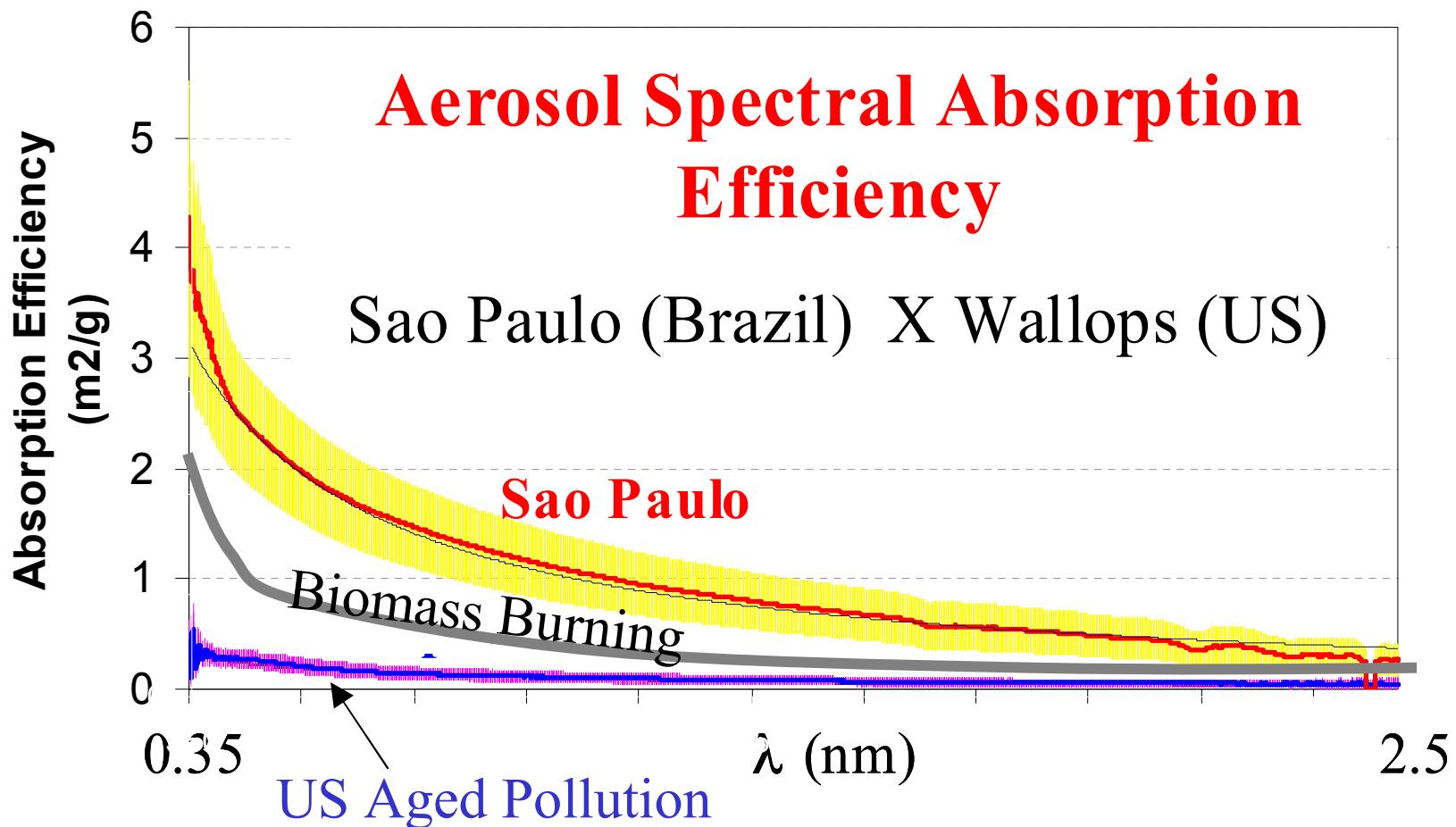


# Sao Paulo – Aerosol Absorption Efficiency

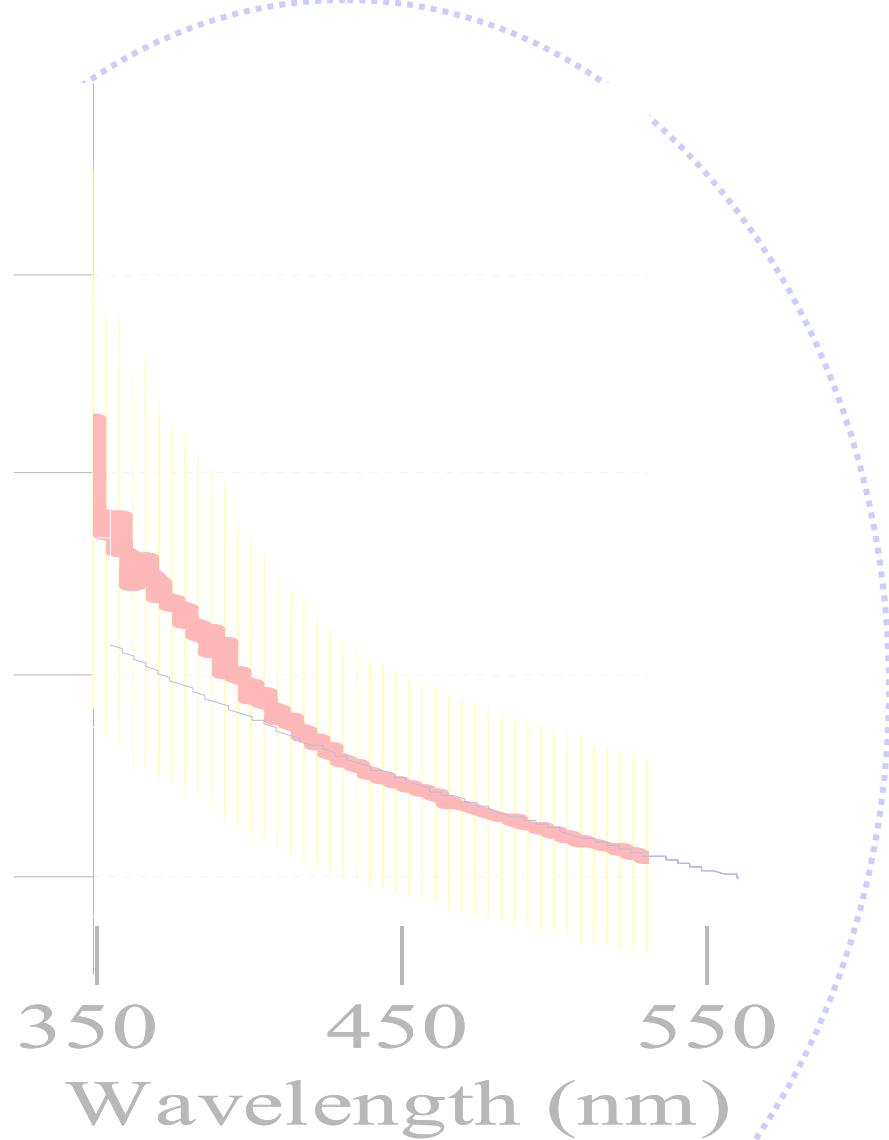
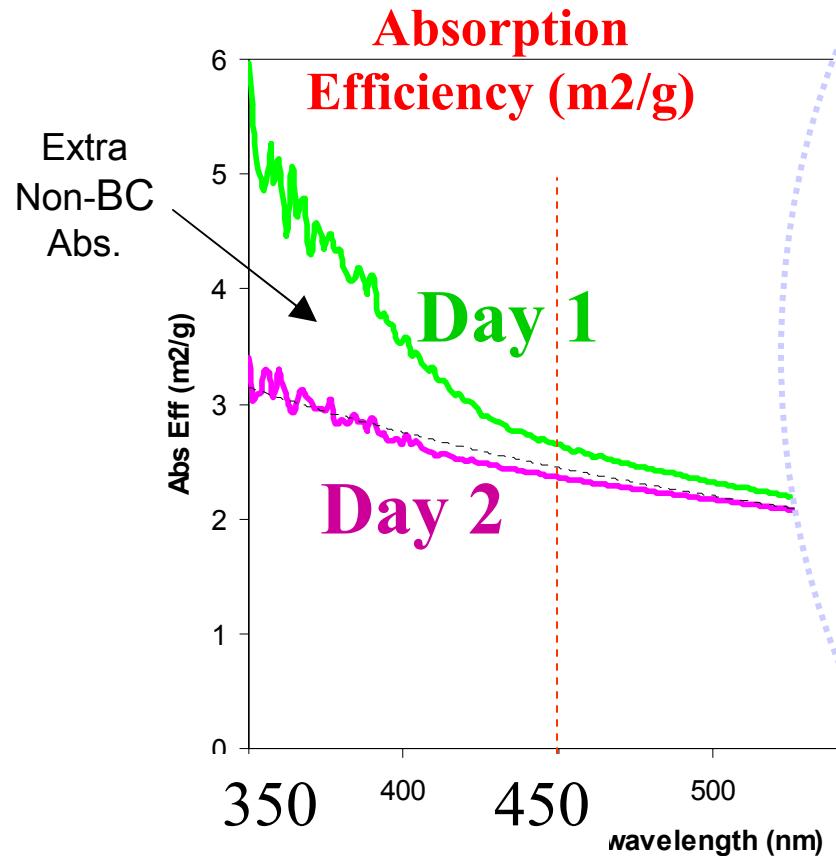
## Size Distributions - AERONET



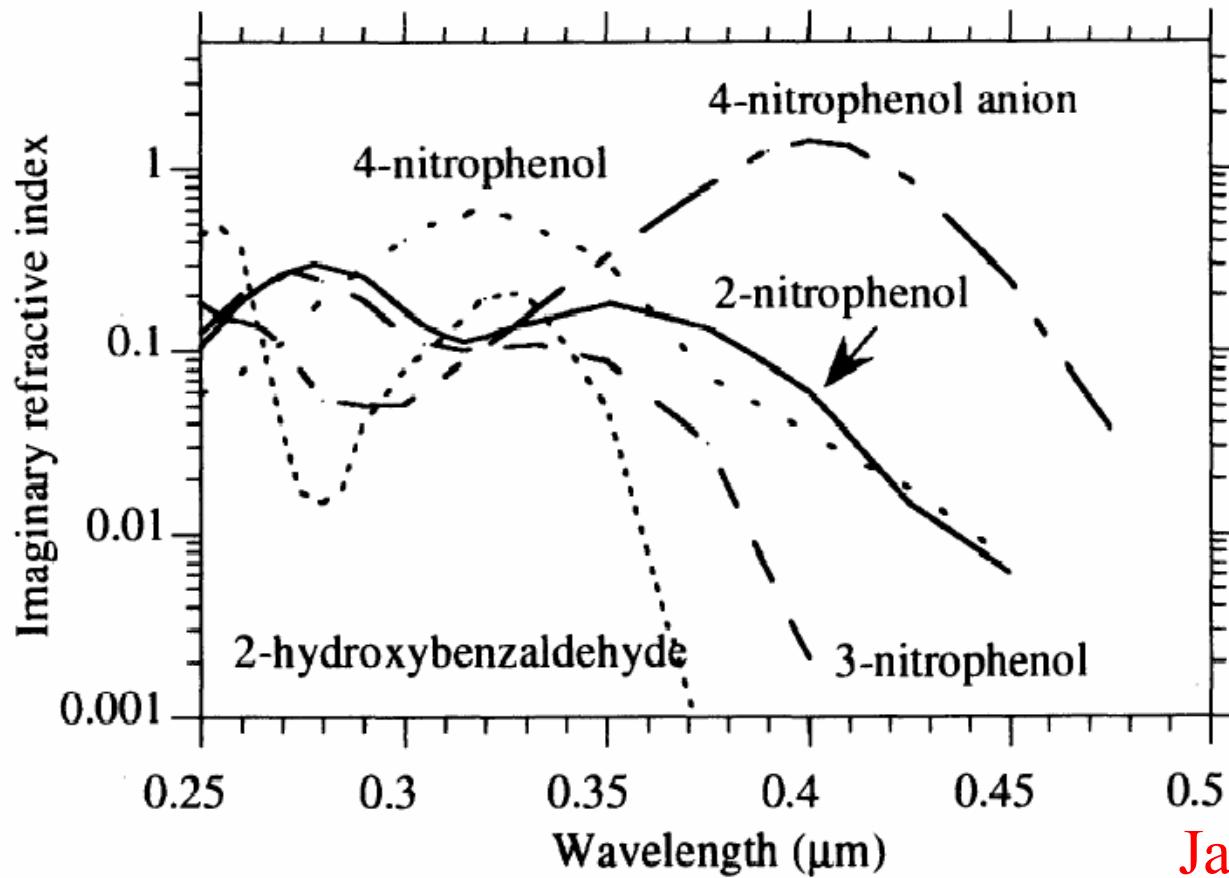
# Pollution from developing countries is highly absorbing!!!



# Extra Non-Black Carbon Absorption

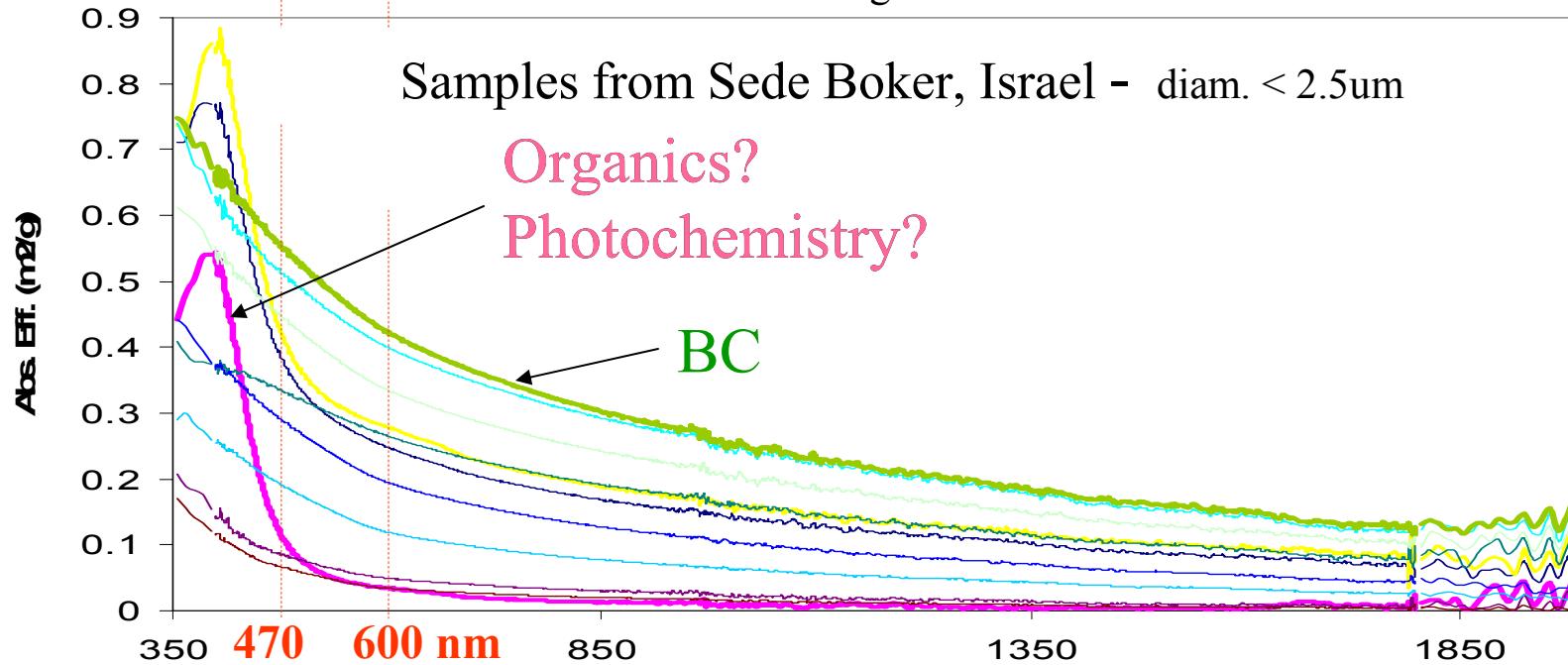
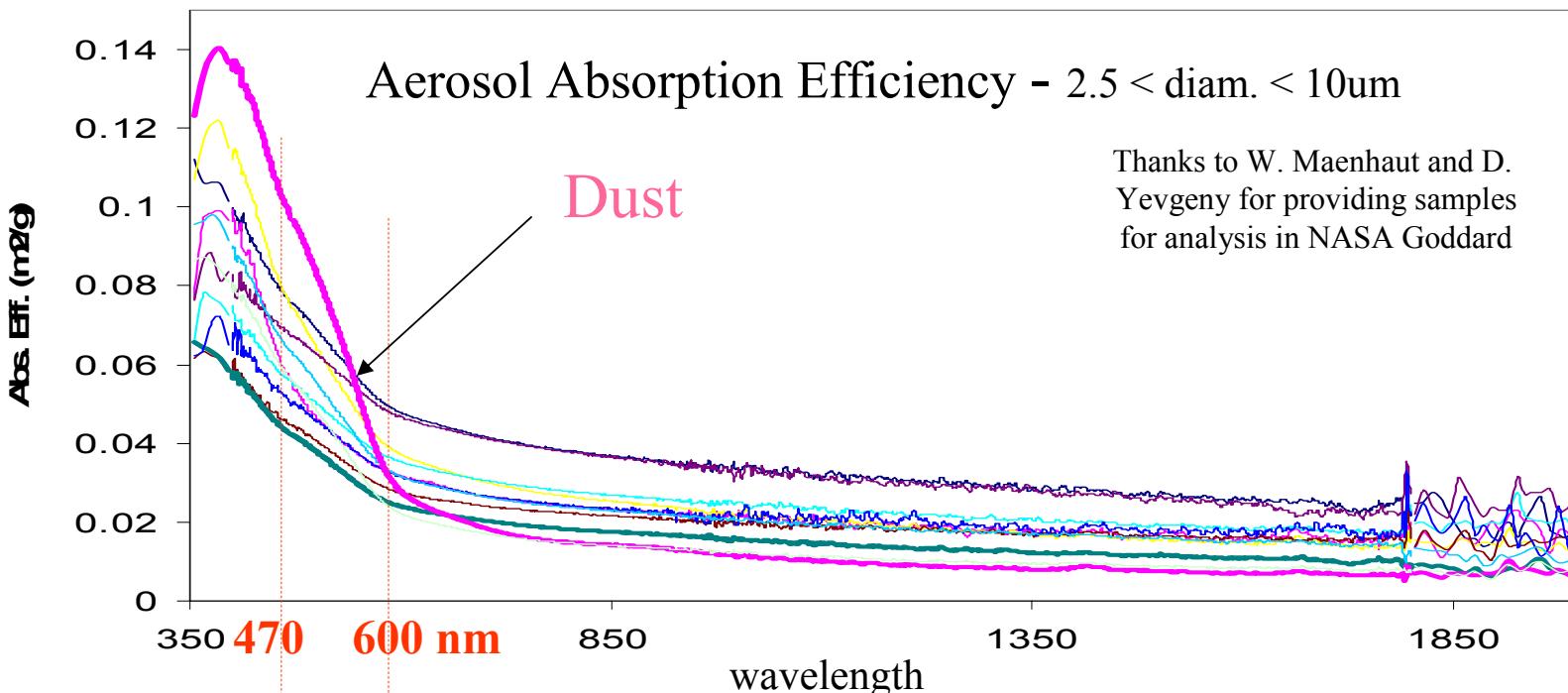


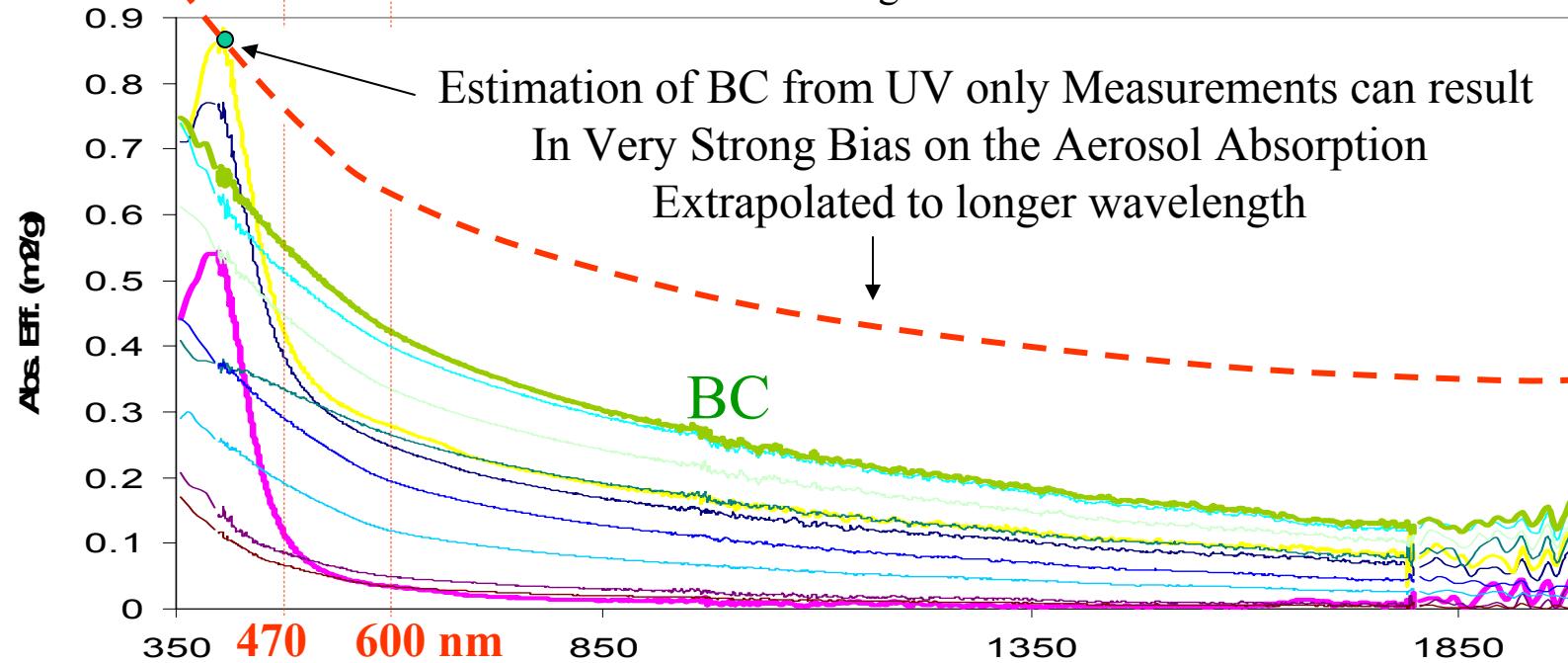
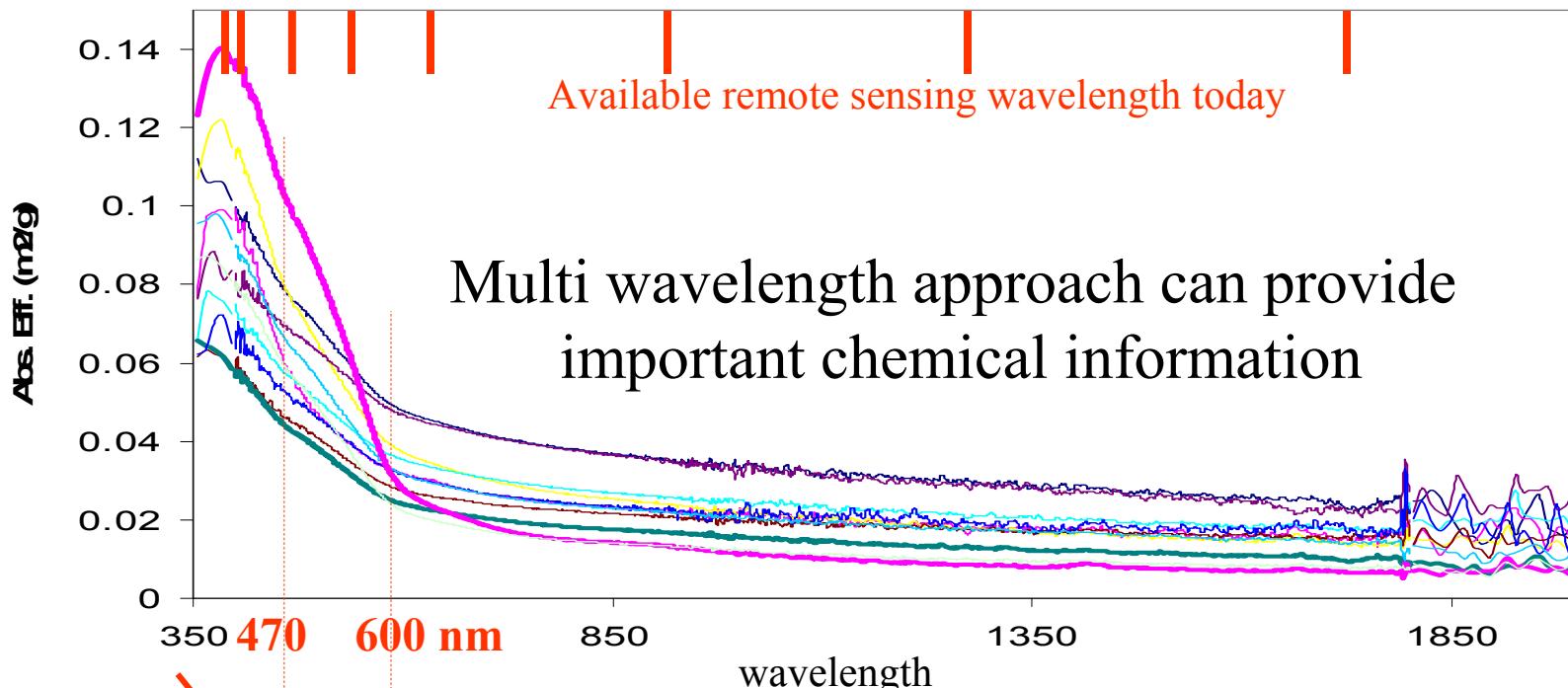
# Imaginary Refractive indices for atmospheric organic material



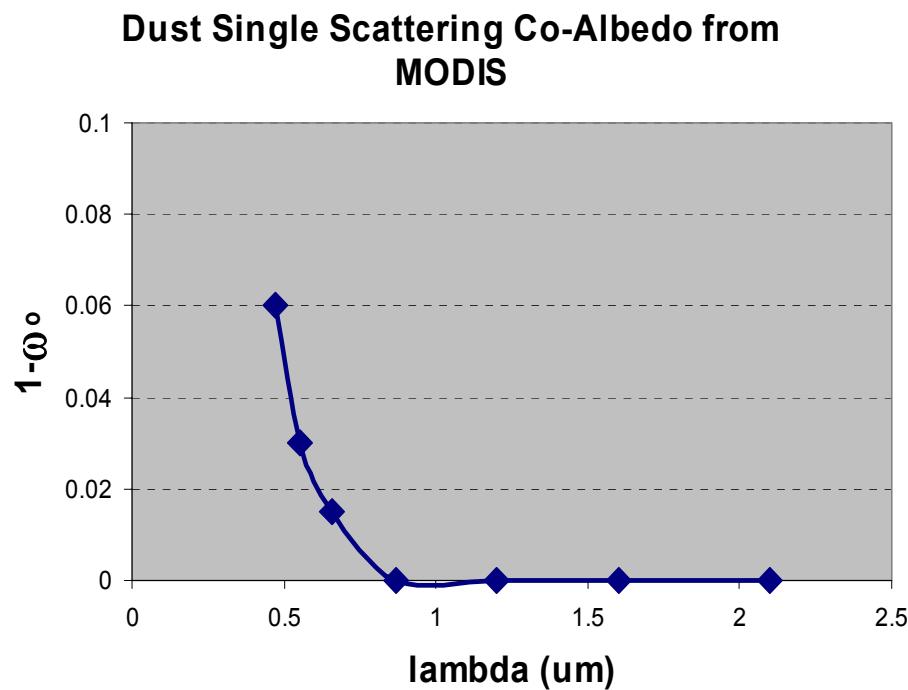
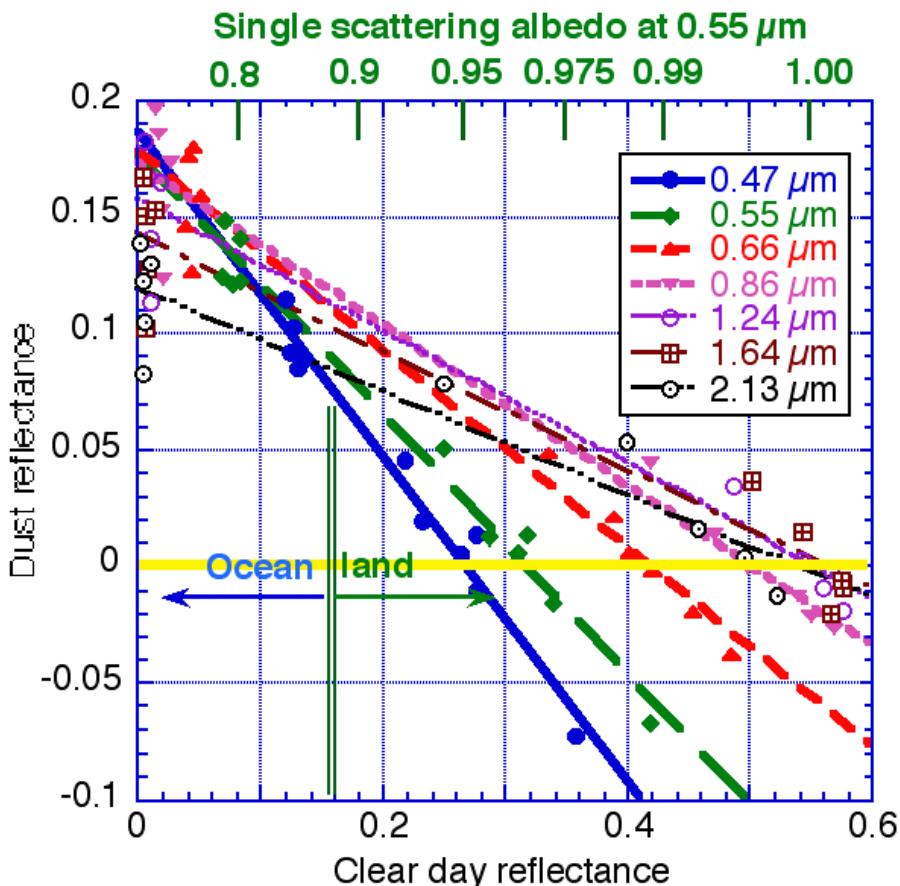
Jacobson et al.,

**Figure 2.** Imaginary indices of refraction of five nitrated and/or aromatic particulate organic substances observed in the atmosphere or in emissions (see Table 3 for observation references). Values were calculated from (6) using information (densities, molecular weights) from Table 3 and spectral molar absorption coefficient data ( $\epsilon$ , base 10) from *Perkampus*





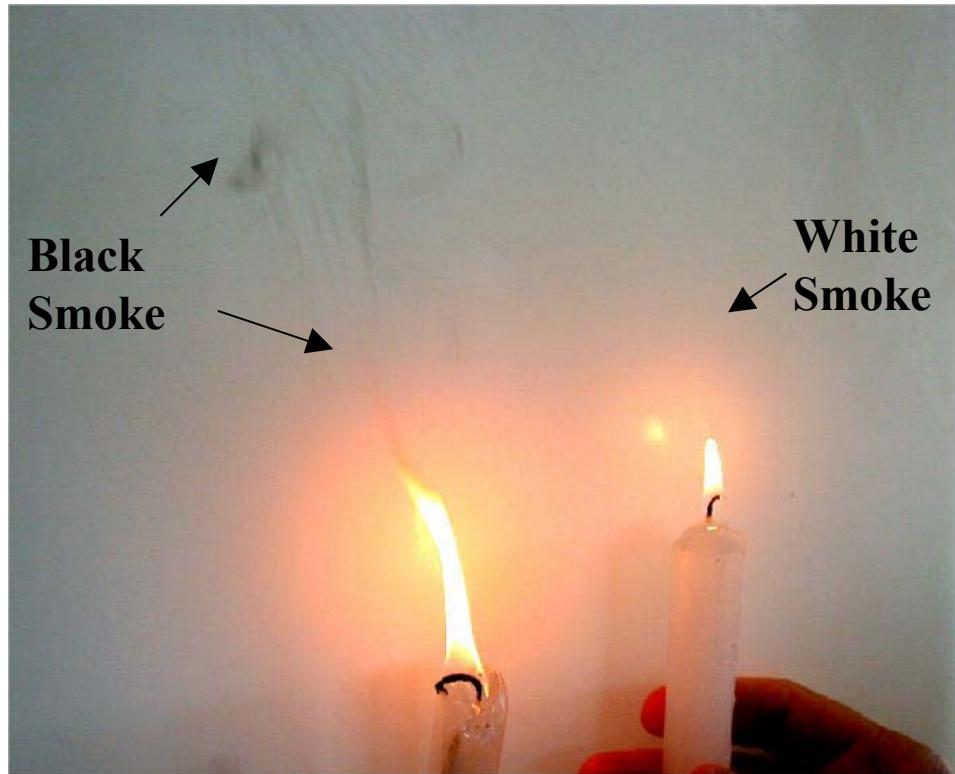
# Remote Sensing of Aerosol Absorption



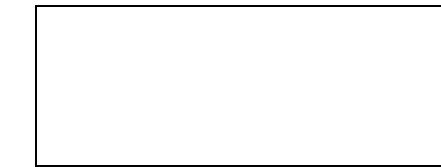
Derivation of the single scattering albedo of dust from MODIS spectral measurements  
The spectral single scattering albedo is 0.94 in the blue ( $0.47 \mu\text{m}$ ), 0.97 in the green ( $0.55 \mu\text{m}$ ), 0.985 in the red ( $0.66 \mu\text{m}$ ) and 1.00 for longer wavelengths.

# AEROSOL DIRECT RADIATIVE FORCING

Variation in BC concentration  
and Properties Relative to the  
white Background



$A_{TOA} < A_{SUP}$   
Warming



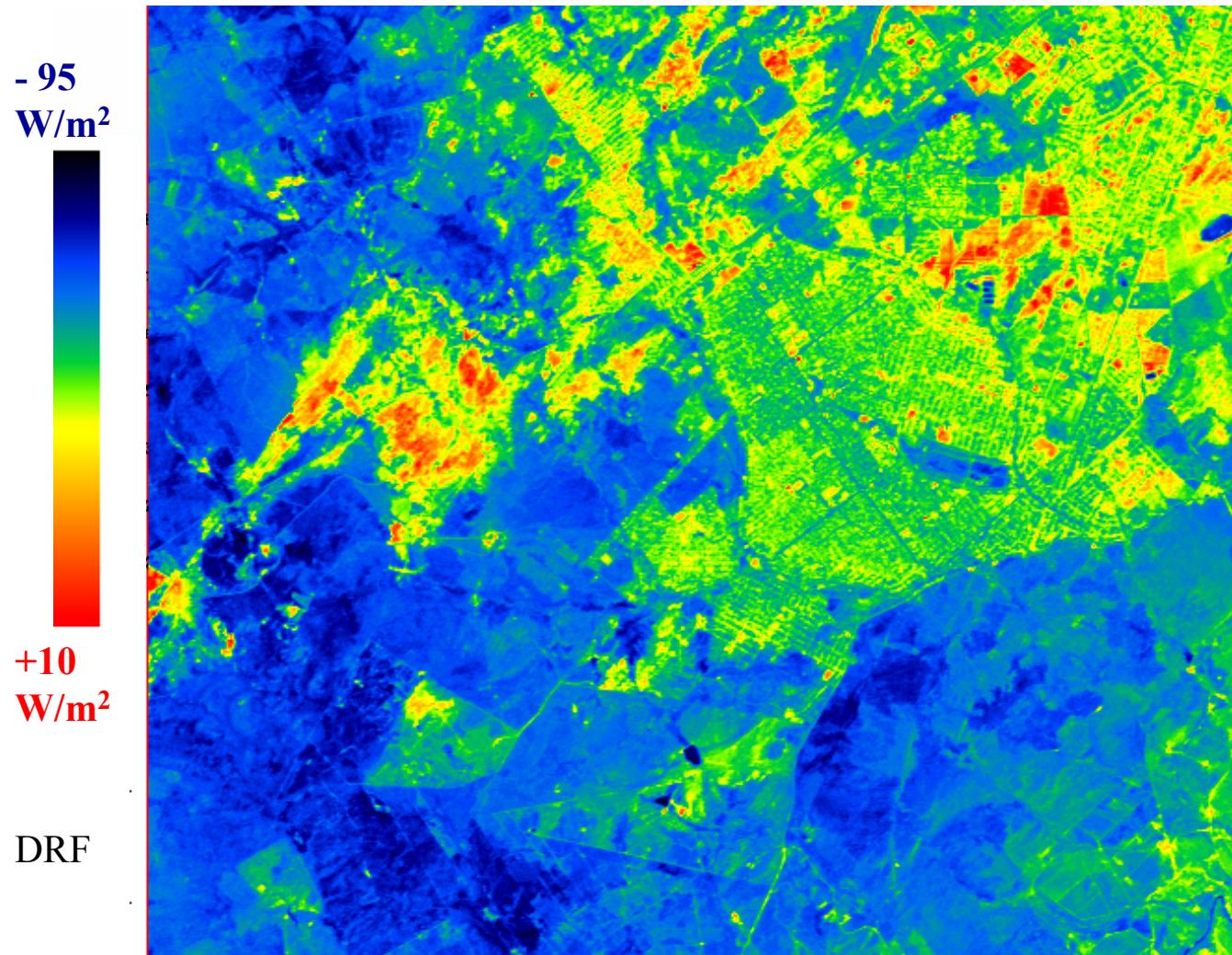
$A_{TOA} = A_{SUP}$   
Balance



$A_{TOA} > A_{SUP}$   
Cooling



# Smoke – Instantaneous Direct Radiative Forcing over Varying Surface Albedo (Cuiaba – Brazil) for $\tau = 1$

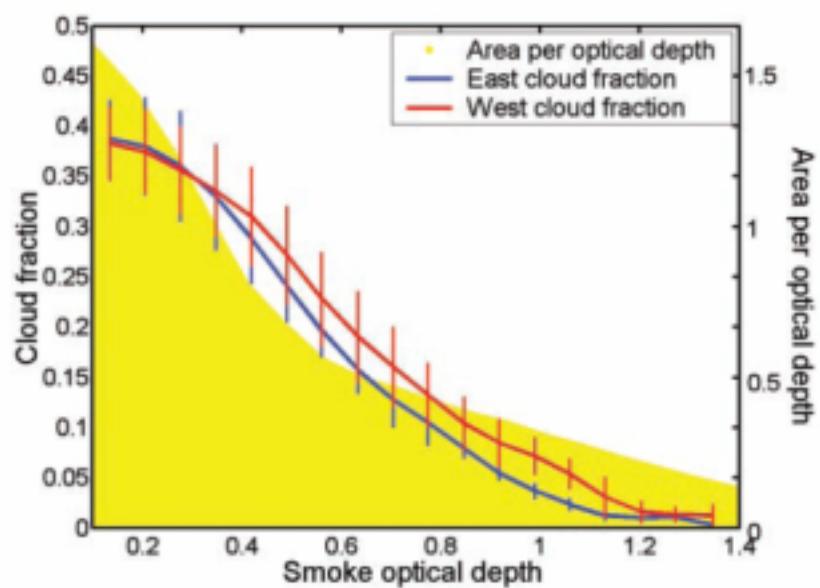
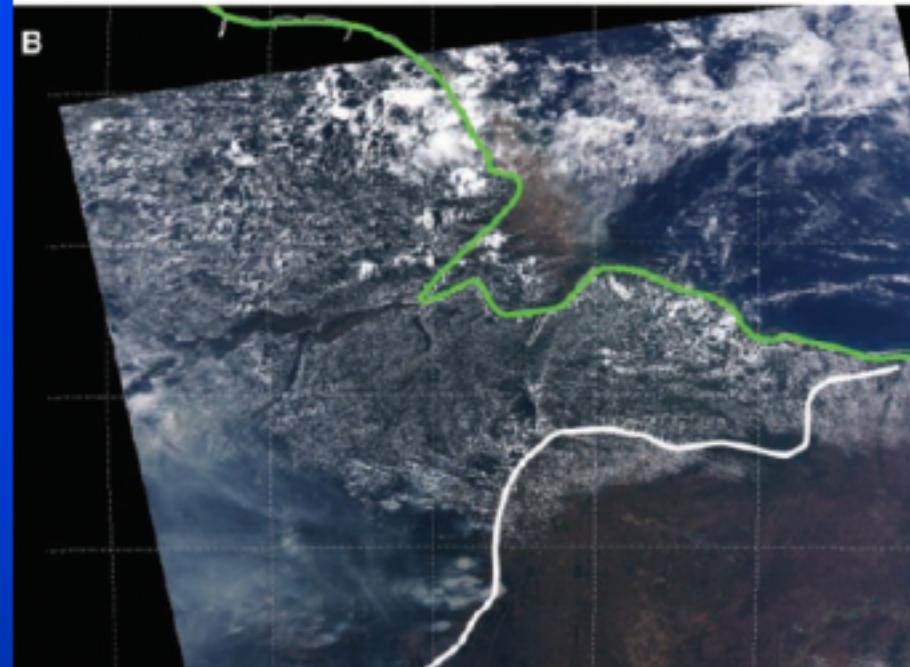
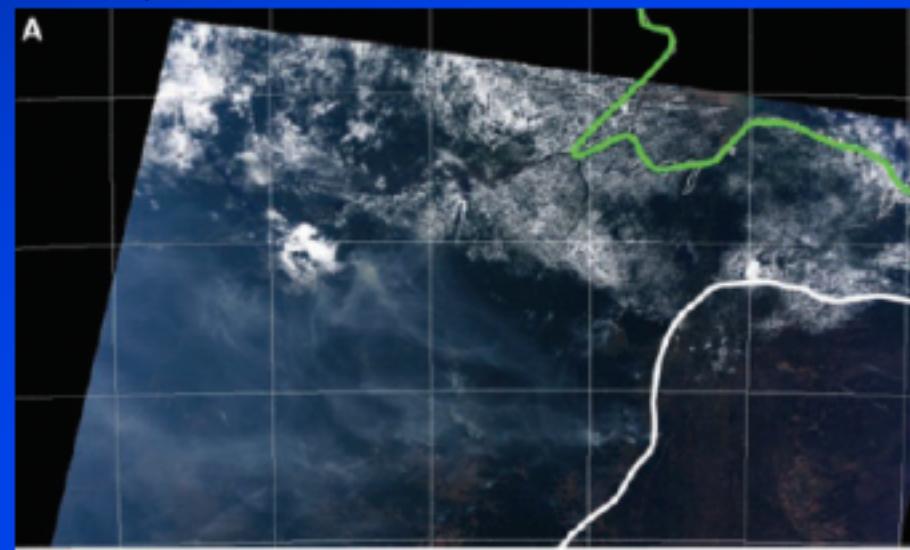
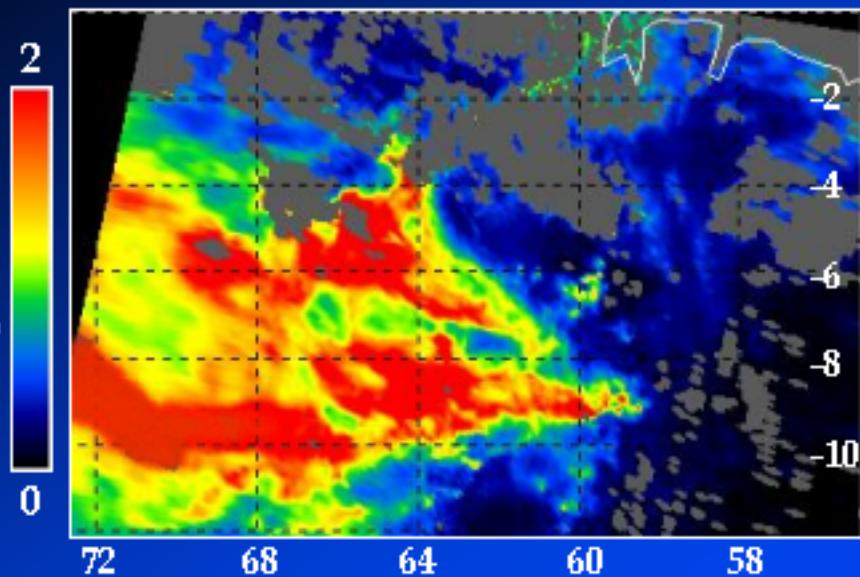


Large contrast in radiative forcing due to the combination of surface and aerosol properties

# 2004 Science Paper - Inhibition of Cloud Formation by Smoke

Koren, Kaufman, Remer, Martins

Aerosol Optical Thickness



GSFC

# SUMMARY:

- **Answering some of the Common Myths about Aerosol Absorption:**
  - The main aerosol absorbers in the atmosphere are Dust and Black Carbon
  - Black carbon also appears on coarse mode particles with very significant effects
  - Dust absorption we observed has very strong spectral dependence from UV-VIS and almost no Absorption in the NIR unless mixed with BC
  - Some organic aerosols have very strong absorption in the UV (2X BC) and some also show significant absorption in the Visible and NIR

